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The Effects of Image and Label on the Free Recall of Movement Lists

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Dédicace à mon mari.

A celui qui m'a donné le goût d'aller plus loin
A celui qui a plaçé tout son espoir en moi
A celui qui m'a encouragé dans les moments difficiles
A celui qui m'a porté toute son affection
A celui que je ne cesserai d'aimer.

ABSTRACT

Seven experiments were conducted on the effects of image and label on the free recall of movement lists. The movements were made with a joystick, and vision was eliminated. The subject while sitting, was able to move the joystick in all directions in the horizontal plane, within a circular area.

A serial position effect was evident for the lists of 10 and 12 movements but was nonexistant when the lists were shorter (3, 4, 5, 7 items). The subjects always demonstrated tendencies to group or organize the movements within the lists, especially when they could form geometric shapes. When such strategies of grouping were used the serial position curve was disturbed. The serial position results of this series of experiments were discussed in terms of a single memory process.

The subjects demonstrated capabilities to label some movement patterns and to maintain mental images of these patterns. The movement patterns that they could label were called "high meaningful". It was found that movement patterns vary in level of meaningfulness.

The recall accuracy was significantly improved when imagery and labelling were suggested as recall strategies, for high meaningful movement patterns. However, the memory loss after 24 hours was significant even with the use of strategies. The recall accuracy was not improved for the

immediate recall of low meaningful movement patterns, when imagery and labelling strategies were proposed. However, the imagery strategy prevented the decay of low meaningful movement patterns, after 24 hours.

A significant lower recall performance was found for the low meaningful movement patterns compared to the high meaningful ones. However, there was no difference in recall performance between high and low meaningful movement patterns, for the control (no strategy) and imagery groups. The only difference existed between the high and low meaningful labelling groups. It was suggested that this difference was a result of the relevance or irrelevance of the given labels.

The recall performances of the high and low meaningful movement patterns, with or without the use of image and labels, were discussed in relation with the dual-coding hypothesis postulated by Paivio (1971) and Paivio & Csapo (1973), with respect to the encoding of movement information.

RESUME

Une série de sept expériences ont été réalisées dans le but de déterminer si la rétention à court et à long-terme de séquences de mouvements était améliorée lorsque des sujets utilisaient des stratégies d'imagerie (imagery) et d'étiquetage (labelling) de mouvements. Le paradigme de recherche consistait en des rappels libres de séquences de mouvements qui avaient été préalablement présentées par l'expérimentateur. Les mouvements étaient présentés de façon kinesthésique à l'aide d'un levier, alors que le sujet avait les yeux bandés. Le sujet se trouvait assis pour toute la durée de l'expérience et pouvait manipuler le levier dans toutes les directions sur le plan horizontal, à l'intérieur d'une région circulaire (voir Plate 1, 2).

Les résultats ont démontré que la courbe de position sérielle était évidente dans le cas des séquences de 10 et 12 mouvements, mais inexistante pour les séquences de 3, 4, 5, et 7 mouvements. Les sujets démontrèrent des tendances à grouper ou à organiser les séquences de mouvements, spécifiquement lorsque ces dernières dessinaient des formes géométriques. Lorsque les sujets utilisaient de telles stratégies pour grouper les informations, la courbe de position sérielle se trouvait perturbée. Les résultats, tels que reproduit graphiquement pour chaque position sérielle, ont été discutés en fonction de la théorie d'une trace unique de mémoire.

Les sujets démontrèrent des capacités évidentes à étiqueter certains patrons de mouvements et à maintenir une

représentation mentale (image) de ces patrons de mouvements. Les patrons de mouvements qu'ils pouvaient étiqueter furent désignés "hautement significatifs" et ceux qu'ils étaient incapables d'étiqueter, "dénués de signification". Les résultats ont démontré que les patrons de mouvements diffèrent grandement quant à leur niveau de signification (élevé, moins élevé, bas).

La précision du rappel était significativement améliorée lorsque des stratégies d'imagerie et d'étiquetage étaient utilisées pour les patrons de mouvements trouvés "hautement significatifs". Cependant, la perte de rétention après 24 heures était évidente, même lorsqu'on utilisait ces stratégies. La précision du rappel immediat n'était pas améliorée pour les patrons de mouvements trouvés "dénués de signification", lorsque les mêmes stratégies étaient utilisées. Cependant, l'utilisation de la stratégie d'imagerie empêcha la perte de rétention des mouvements "dénués de sens", après 24 heures.

Une performance motrice significativement plus basse a été observée pour les mouvements "dénués de sens", comparativement aux mouvements "hautement significatifs". Cependant, cette dernière observation demeure vraie seulement pour les groupes qui utilisent une stratégie d'étiquetage. Aucune différence significative en tant que précision du rappel n'a été trouvée entre les mouvements "hautement significatifs" et "dénués de sens", pour les groupes contrôle (qui n'utilisèrent pas de stratégie) et les groupes qui utilisèrent une

stratégie d'imagerie. Ces données ont semblé indiquer que cette différence résultait de la pertinence ou de l'impertinence d'une stratégie d'étiquetage (associer un ou plusieurs mots à un ou plusieurs mouvements) pour la rétention de séquences de mouvements. De plus, il a été proposé que l'étiquetage rendait une séquence de mouvements "significative" pour le sujet.

Les performances motrices des patrons de mouvements "hautement significatifs" et "dénués de sens", avec ou sans l'utilisation de stratégies d'imagerie et/ou d'étiquetage, ont été discutées dans la section "discussion générale" en fonction de l'hypothèse de double codification de l'information, postulée par Paivio (1971) et Paivio & Csapo (1973).

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LIST OF ABBREVIATIONS

C	Control
E	Experimenter
I	Imagery
I+L	Imagery+labelling
K	Kinesthetic
L	Labelling
M	Meaningful / meaningfulness
S	Subject
SPC	Serial position curve

The study of memory will be the focus of this series of investigations. The information transmitted in this thesis is mainly based upon verbal memory.

According to Murdock (1974) there are three main types of information that, to date, have been identified as important in human memory. They are 'item information', 'associative information', and 'order information'. "Item information enables us to remember objects and events, to recognize names, faces, pictures, musical compositions, tastes, smells, and much else that we encounter in our everyday life. Associative information, or associations, relate two things: names and faces, for instance, or words and meaning, or composers and compositions. Order information refers to the memory for sequences of events or strings of items: the letters of the alphabet, the days of the week, or the spelling of words" (Murdock, 1974, p. 2). In this set of experiments, 'item information' refers to movement items; 'associative information' to the relation between movements, internal images and words; and 'order information' to the memory for lists of movements.

The basic question to consider is how this information is represented in memory - or, what is stored, how it changes over time, and how it is used at the time of test (Murdock, 1974). That is, the basic questions pertain to the encoding, retention, and retrieval of these types of information. Encoding refers to what is stored (Murdock, 1974) and is generally considered to involve the transformation of the

stimulus into some sort of representation (Sternberg, 1969) and in some cases the naming of the stimulus (Theios, 1973). Retention refers generally to the act of holding the information in memory; in this set of investigations the information is held for future recall. Retrieval in this set of experiments, refers to the act of recalling the information.

To date, the motor memory literature only concerns a review of article on long-term memory (Stelmach, 1974) and a great number of studies in short-term memory (Adams & Dijkstra, 1966; Montague & Hillix, 1968; Ascoli & Schmidt, 1969; Stelmach & Wilson, 1970; Pepper & Herman, 1970; Stelmach & Bassin, 1971; Roy & Davenport, 1972; Keele & Ells, 1972; Laabs, 1973; Roy, 1975). However, these authors were concerned only with single item presentations. None of the latter considered the encoding, retention, and retrieval characteristics of multiple items. For instance, Laabs (1973) asked for the recall of movement distance and location. The paradigm he used, as well as the aformentioned authors, was a short-term memory paradigm for the recall of single items. In other words, for all the authors mentioned previously, each movement was tested individually for recall. Therefore, there was no possibility of looking at the encoding, retention and retrieval characteristics of associative movement information and/or serial-order information.

For the present writer, the lack of work on multiple items, as found in lists in verbal experiments, demonstrate

the weakness of the motor memory literature. It is certainly very important to determine the nature of motor memory by means other than the single item - Brown-Peterson distractor paradigm - namely information gained by using multiple items in a serial position curve arrangement.

Since we do not know if a serial position curve exists for motor memory, this investigation should be done. The problem of Experiment 1 was to determine if a serial position curve existed in motor memory, by using a free recall paradigm.

Experiment 1

Serial position recall in short-term motor memory

The serial position curve (SPC) in verbal literature presents some general characteristics, and the form of this distribution is so stable and so consistant that we need not hesitate to call it a certainty.

The SPC resulting from a free verbal recall paradigm, is generally characterized by what Murdock (1962) called "primacy effect", "recency effect" and an horizontal "asymptote". The primacy is usually extending over the first three or four items in the list and is less in magnitude than the recency effect; an S-shaped recency effect, marked with amplitude, is extending over the last eight items of the list, and an horizontal asymptote is spanning the primacy and recency effect.

The manner in which the primacy and recency effect are related to the acquisition of a serial motor task, has been investigated by Cratty (1963), Zaichkowsky (1974) and Magill (1976). The purpose of those studies was to investigate the order of acquisition by the learner of the parts of a serial motor task to determine if the primacy and recency effect generally found in serial verbal tasks also exists for serial motor tasks. However, for all the experiments done in serial motor tasks, none of them indicated the typical J-shaped curve found for learning serial verbal tasks. The results indicated no recency effect and were interpreted in terms of proactive interference, since the last items, which were recalled last, were considered to be interfered by the preceeding ones.

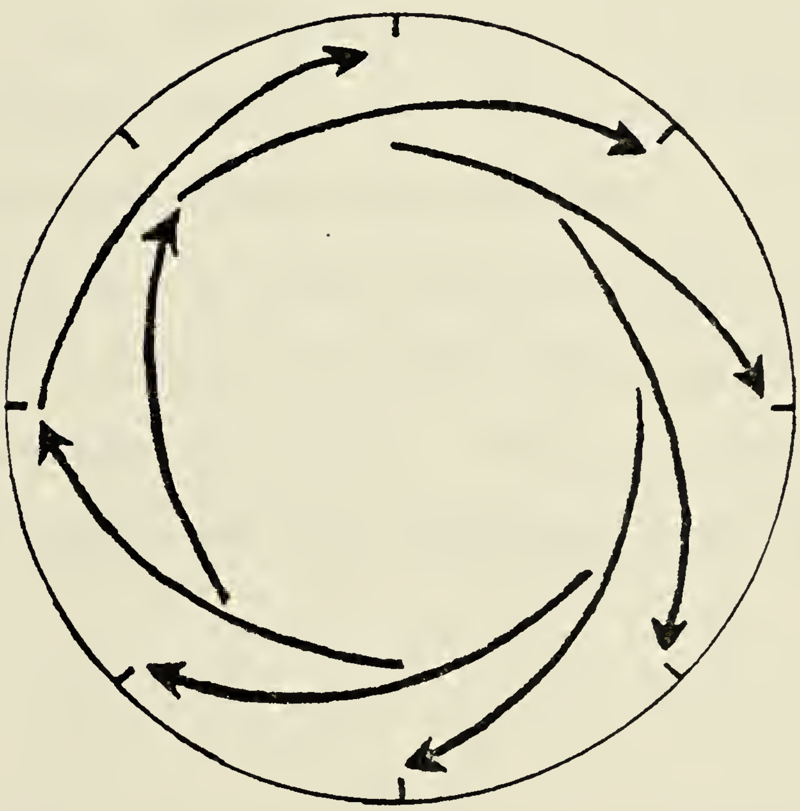
However, a recent study investigated by Wrisberg (1975) indicated a clear J-shaped serial position curve, for a serial motor task. In this particular experiment, five positions were given for a single presentation and the subject (S) had to recall the positions in reverse order of presentation, from the fifth to the first position. Therefore, since the first position reproduced was the last one of the list, or the more recent in memory, a clear recency effect was found. Those results, opposed to Cratty (1963), Zaichkowsky (1974) and Magill (1976) could be due to the methodology used, where the Ss of the last three studies had to report the items in order of presentation.

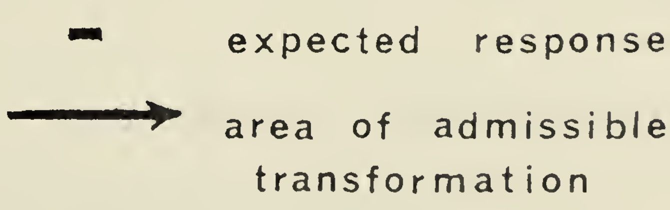
It seems that, up to this time, there was no study conducted to investigate the relation of a primacy and a recency effect with a free motor task. Therefore, this study has been designed to find out if a J-shaped SPC exists in motor short-term memory, by using a free recall paradigm. And, in order to attenuate the confusion for the S, between several different kinesthetic items, the movements were defined theoretically in terms of uniqueness. Uniqueness itself has been defined in measurement by the notion of admissible transformation (Coombs, Dawes and Tversky, 1970) (Figure 1).

FIGURE 1

AREA OF ADMISSIBLE TRANSFORMATION:

45° EITHER SIDE OF THE EXPECTED RESPONSE





Method

Subjects

The subjects were eight volunteers, graduate students at the University of Alberta.

Apparatus and task

A joystick, with a radius of 13 inches, could move in two dimensions within a circle of nine inches diameter. The S while sitting, was able to move the joystick in all directions in the horizontal plane. The information load varied by requiring the S to recall a certain number of movement triangles within this region.

To initiate the input phase of each triangle and the recall of each sequence of triangles, an EICO auditory tone generator was activated. The S was provided with a set of mono headphones with which he could hear the signal tones.

Design

The experimental design was a treatment x subjects design with repeated measures of the same subjects under each experimental treatment.

The four treatments, determined by logarithmic increment (base 2), were the sequence lengths of 3, 4, 5, and 7 triangles.

The order of presentation was random and independently

determined for each S, from a range of eight unique triangles.

Procedure

Each S was individually tested in a single session during approximately 30 minutes and received verbal instructions prior to the testing (Appendix A).

Each S remained seated in a comfortable chair, was blindfolded and set the headphones for the practice and all the experiment. The apparatus was located at the S's right or left side (depending on his prefered hand) in such a way that he could move the lever freely anywhere within its entire range.

Before the practice trial, the eight triangles which constituted the experiment were described by the E, by moving the joystick in different directions, while the S's hand was always on the lever. The practice trial was given in the same experimental conditions.

The following events constituted a single experimental trial. A single tone indicated to the S that a triangle was described for him by the E, while his hand was on the lever (passive movement). Each time a triangle was described for the S, he heard a single tone. When the S heard two successive tones, he had to recall the sequence of triangles given before, by moving the lever by himself. The S could recall the sequence of triangles in any order he wanted.

The starting and ending points were the same for each triangle, and the rate of presentation was two seconds per

movement, leaving three seconds between each triangle.

Only an immediate recall was used for the experiment. Each S received twenty different sequences or five replications of each of the four sequence lengths.

Data analysis

The data were recorded in terms of percent correct recall (dependent variable), for each serial position (independent variable). Two different ways of recording the data were taken in consideration. First, under an all-or-none basis, the percent correct triangles recalled for each serial position were recorded (the whole triangle was correct or not). Second, the percent correct movements recalled for each serial position were recorded (the three movements of each triangle were considered by giving one point for each correct movement).

For all statistical tests performed on the data as presented in the following section, the criterion for rejecting the null hypothesis was $p < .01$.

Results

Two types of measures were used to record the data: first, the number of correct triangles and second, the number of correct movements.

Correct triangles

Significant differences between the four sequence lengths, $F(3,21) = 4.77$, $p < .01$, were provided by the analysis of variance. The results obtained from the Scheffé post hoc comparison test revealed that the significant differences were located between the sequences of 3 and 7 triangles, at the level $p < .05$ (Appendix B).

Correct movements

By using the second type of measure, the number of correct movements, the following results were recorded. A significant main effect between the four sequence lengths, $F(3,21) = 7.13$, $p < .005$, was provided by the analysis of variance. The results obtained from the Scheffé post hoc comparison test revealed that the significant differences were located between the sequences of 9 and 21 movements, at the level $p < .01$ (Appendix B).

As presented in Figures 2 and 3, there is an overall depression produced between the sequences of 9 and 21 movements. The mean recall for each sequence length condition is presented in Table 1.

FIGURE 2

PERCENT CORRECT MOVEMENTS RECALLED FOR EACH SERIAL POSITION

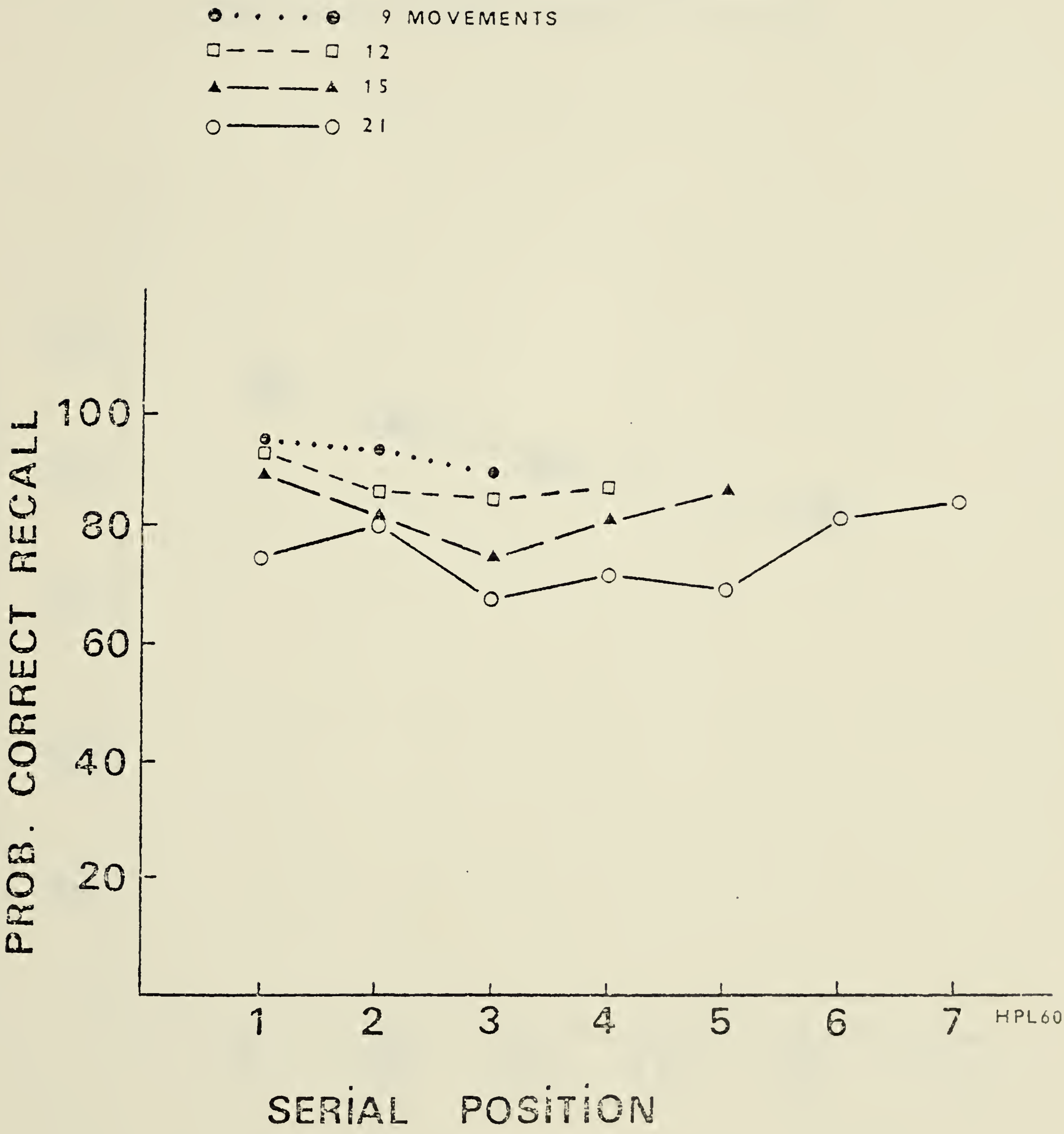


FIGURE 3

PERCENT CORRECT MOVEMENTS RECALLED

UNDER EACH SEQUENCE LENGTH CONDITION

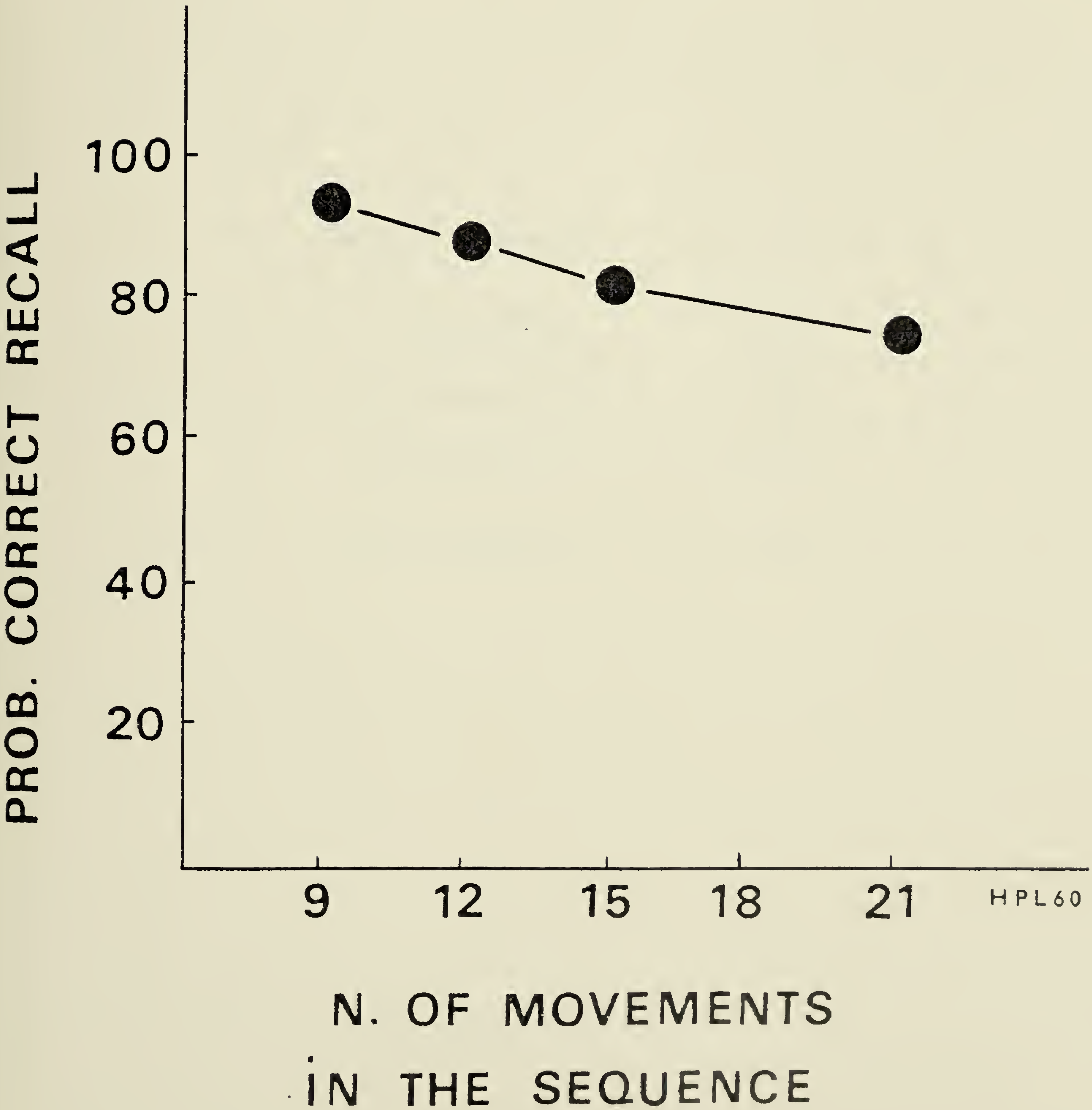


TABLE 1

MEAN CORRECT MOVEMENTS RECALLED

UNDER EACH SEQUENCE LENGTH CONDITION

Sequence length	$\bar{X}$
9 movements	0.930
12 movements	0.881
15 movements	0.830
21 movements	0.760

Discussion

The results failed to demonstrate the shape of a SPC (Figure 2) either by using the measure by triangles or all-or-none measure (used in verbal literature) or by using the measure by movements or components. However, there was a significant depression of the curve when the number of triangles or movements in the sequence was increased from 3 to 7 for the triangles, and from 9 to 21 for the movements (Figure 3).

The last finding supports Murdock's (1962) results, who found a significant overall depression of the curve when the list length was increased from 10 to 40 items. However, even if no SPC was found, the results cannot be interpreted in terms of proactive interference, as did Cratty (1963), Zaichkowsky (1974) and Magill (1976). More direct comparisons are not valid since the paradigms used were dissimilar.

Why should there be a difference in the findings of these studies and what could account for the results ? One of the reasons, could be attributed to the small amount of information needed for recall. It seems clear that the Ss chunked (Miller, 1956) the movement items, and therefore the sequences of 9, 12, 15 and 21 movements were encoded as sequences of 3, 4, 5 and 7 triangles.

The ceiling effect demonstrated by a high percent recall (Figure 2) constitute a support for this assumption.

Further, the high recall accuracy in performance suggests that the amount of information was well within the S's memory span. As mentioned by Fitts and Posner (1967), "the memory span for letters is seven items, but the number of letters retainable when they are grouped into words is increased several fold" (p. 66).

Since it is likely that the amount of information was within the memory span, the J-shaped SPC could not be found. This is so because "the serial position effect holds true for lists of any length beyond the memory span" (Klatzky, 1975, p. 8).

The results of this experiment supports Sharp (1971) and Salmela's (1972) findings, to the fact that a S can recall almost perfectly seven sequential bi-dimentional movements or seven bi-dimentional chunks of movements.

A second reason to account for the lack of SPC, could be the small number of movement items available in the movement lexicon; there being only eight unique triangles adhering to the admissible transformation requirement. This could be a cause of the high facilitation in performance. A third reason to account for those results could be due to the definition of uniqueness in terms of quadrants. The definition may have allowed too large an area for admissible transformations of the criterion movements.

Finally, since the differences provided by Scheffé between the sequence lengths of 3 and 7 triangles were significant at the level $p < .05$ for completed triangles,

and were significant at the level $p < .01$ with respect to individual movement items, it would seem that the measurement of individual movement items was the more sensitive dependent variable.

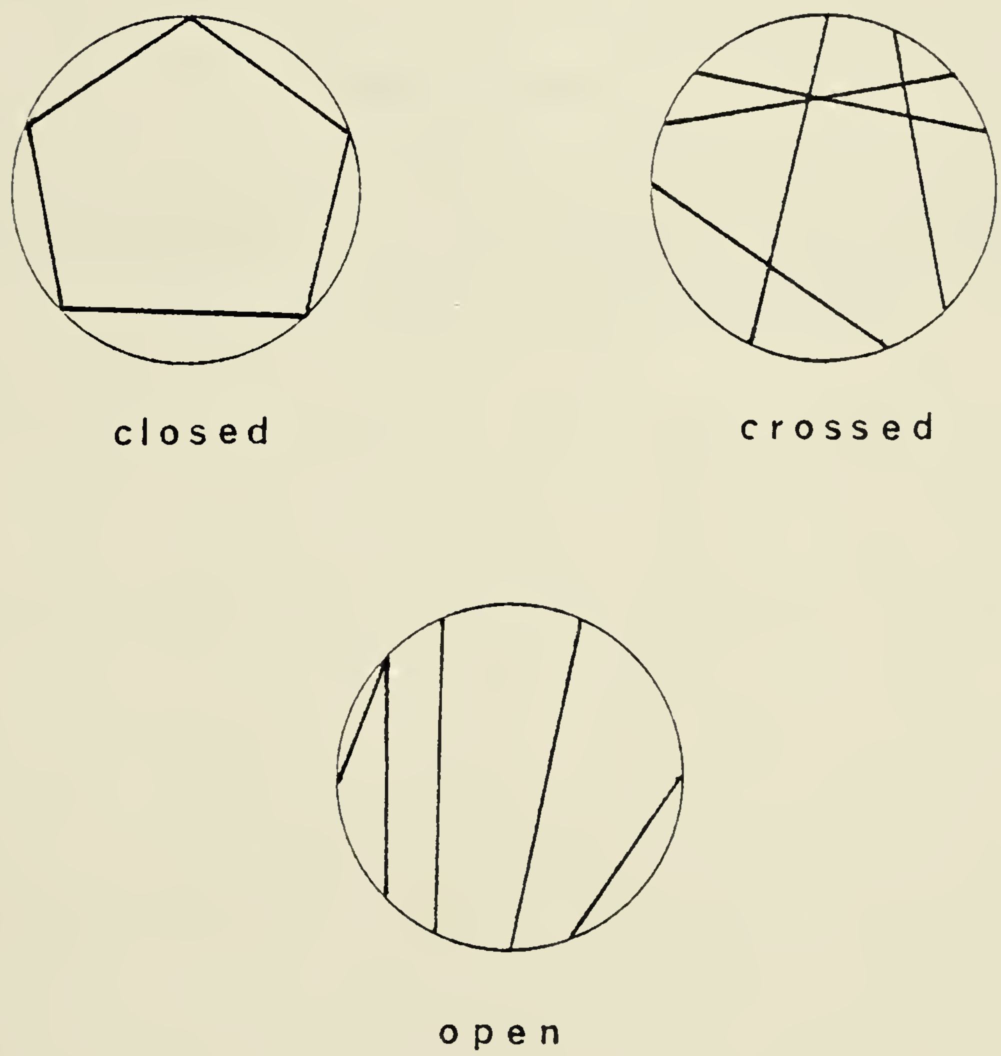
The lack of SPC resulting from Experiment 1, was attributed to many reasons expressed throughout the previous discussion. The main reason has seemed to be the information load which was within the memory span (Klatzky, 1975). Consequently, a further study was designed to determine if a J-shaped SPC is evident in motor memory, when the movement item list length exceeded memory span.

Another variable considered in the study was a variable termed 'movement characteristics'. Three levels of movement characteristics were included in the study: 1) closed, 2) crossed, and 3) open movements (Figure 4). The purpose of including this variable was to investigate the relationship of the SPC to specific characteristics of multiple movement items.

FIGURE 4

GRAPHICAL REPRESENTATION

OF CLOSED, CROSSED, AND OPEN MOVEMENTS



Closed - the movements were forming a closed pattern

Crossed - the movements were crossing each other

Open - the movements could touch but not cross another

Experiment 2

Serial position in short-term motor memory as a function of organization

Method

Subjects

The subjects were eight righthanded volunteers, graduate students in Physical Education at the University of Alberta.

Apparatus and task

A joystick with a radius of 15 inches, could move in two dimensions within a circle of 12 inches diameter. The S while sitting was able to move the joystick in all directions in the horizontal plane. The information load varied by requiring the S to recall a certain number of movements within this region.

In order for the E to give the sequences of movements, and for the S to reproduce them, an EICO auditory tone generator was activated by both the S and the E.

Design

The experimental design was a 3 x 4 x 3 factorial with repeated measures on all factors. The first factor consisted of three levels of movement characteristics : closed, crossed, and open movements. The second factor had four levels of sequence lengths : 5, 7, 10, and 12 movements. The third factor consisted of three replications under each experimental condition.

Procedure

Each S was individually tested in a single session during approximately two hours and received verbal instructions prior to the testing (Appendix A).

Each S remained seated and was blindfolded for all the experiment, including the reading of the instructions. To attenuate the effect of fatigue, the S was told to advise the E when he was physically or mentally tired. Therefore, the S could stop whenever he wanted throughout the experiment. The apparatus was located at the S's right side and the chair was replaced for each S, in such a way that he could move the lever freely anywhere within its entire range.

Since each movement of the sequence had a new starting point, the following events constituted a single experimental trial. The S's hand was on the handle and the E was moving the lever for the S by producing a continuous tone from the beginning to the end of the movement. Then, the E was moving the lever to the new starting point of the following movement, without any signal tone. The S knew from the instructions that he had only to remember the movements given with a signal tone. When the S was hearing two successive tones, then he knew that he had to recall the sequence of movements given before, by moving the lever by himself, and by producing a continuous tone for each movement that was given with a tone in the preceeding sequence. The S could recall the sequence of movements in any order he wanted.

The rate of presentation was three seconds per movement, leaving three seconds to move to a new starting point. There was no restriction of time for the recall. Only an immediate recall was used for the experiment.

Data analysis

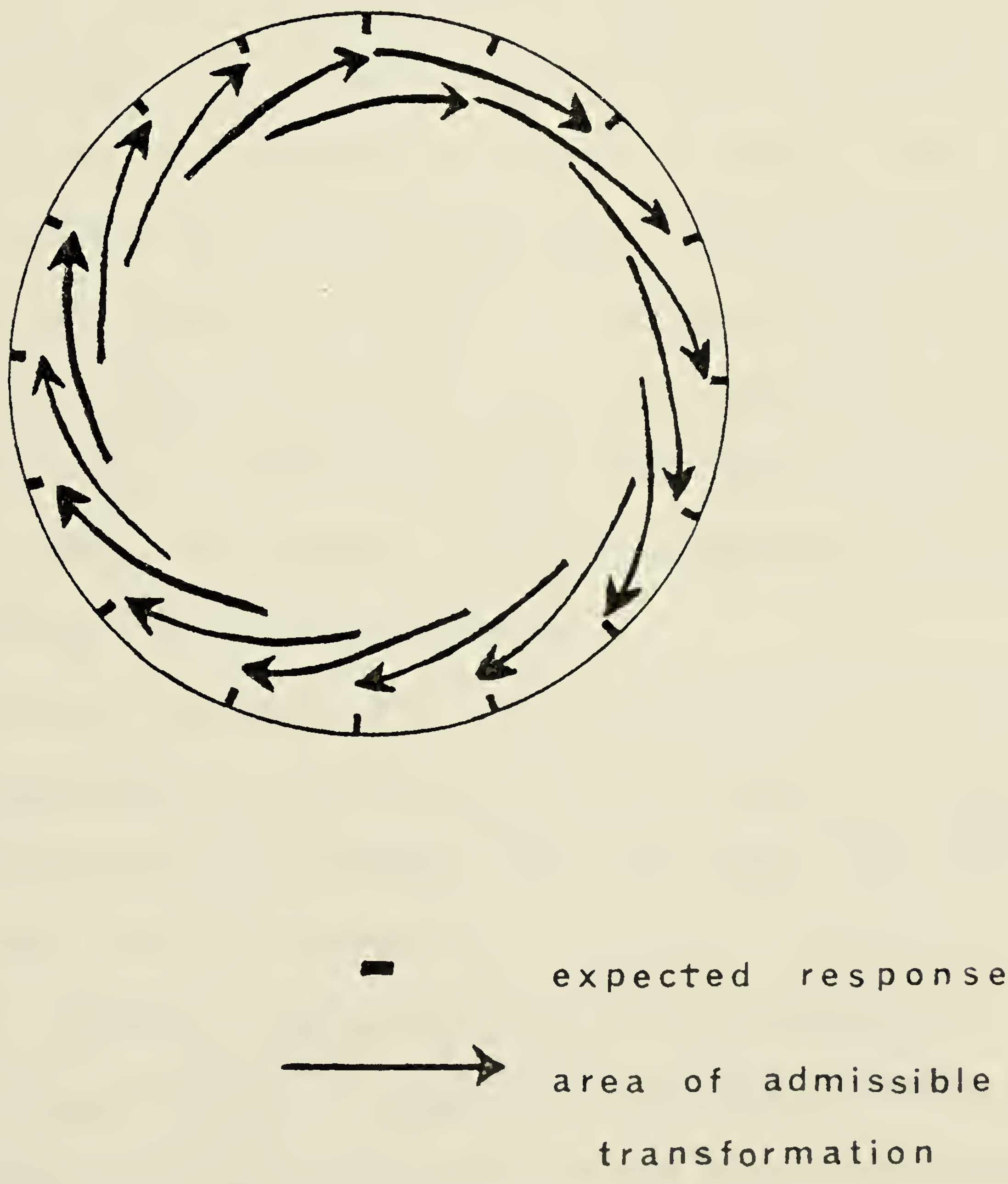
The data were recorded in terms of percentage of correct recall (dependent variable), for each serial position (independent variable). In order to record the data, the amount of admissible transformation has been restricted to 22.5° either side of the expected response (Figure 5).

For all statistical tests performed on the data, the criterion for rejecting the null hypothesis was $p < .01$.

FIGURE 5

AREA OF ADMISSIBLE TRANSFORMATION:

22.5° EITHER SIDE OF THE EXPECTED RESPONSE



Results

No significant differences were found by the analysis of variance between the three levels of movement characteristics (closed, open, crossed), $F(2,14) = 2.56$, $p > .05$ (Appendix B). However, significant differences were provided by the same analysis between the four levels of sequence lengths, $F(3,21) = 12.03$, $p < .001$, and an interaction effect was found for the movement characteristics x sequence lengths conditions, $F(6,42) = 4.06$, $p < .01$ (Appendix B). The interaction effect presented in Figure 7, reveals that the significant interaction is due to the closed movements. Finally, the same analysis of variance revealed that the three replications used in each experimental condition differed significantly from each other, $F(2,14) = 23.87$, $p < .001$ (Appendix B). The lack of interaction effect found for the replications, suggests that the improvement took place equally through the experimental conditions (Figure 8).

Scheffé was used for post hoc comparisons and revealed that the significant differences for the sequence length conditions were located between the sequences of 5 and 7, 5 and 10, and 5 and 12 movements, at $p < .001$ (Figure 6, Appendix B). Scheffé was also used for the movement characteristics x sequence lengths interaction effect and revealed significant differences for the closed movements between the sequences of 5 and 7, 5 and 10, and 5 and 12 movements, at $p < .01$ (Figure 7, Table 2, Appendix B).

FIGURE 6

PERCENT CORRECT MOVEMENTS RECALLED
UNDER EACH SEQUENCE LENGTH CONDITION

(Movement characteristics are collapsed)

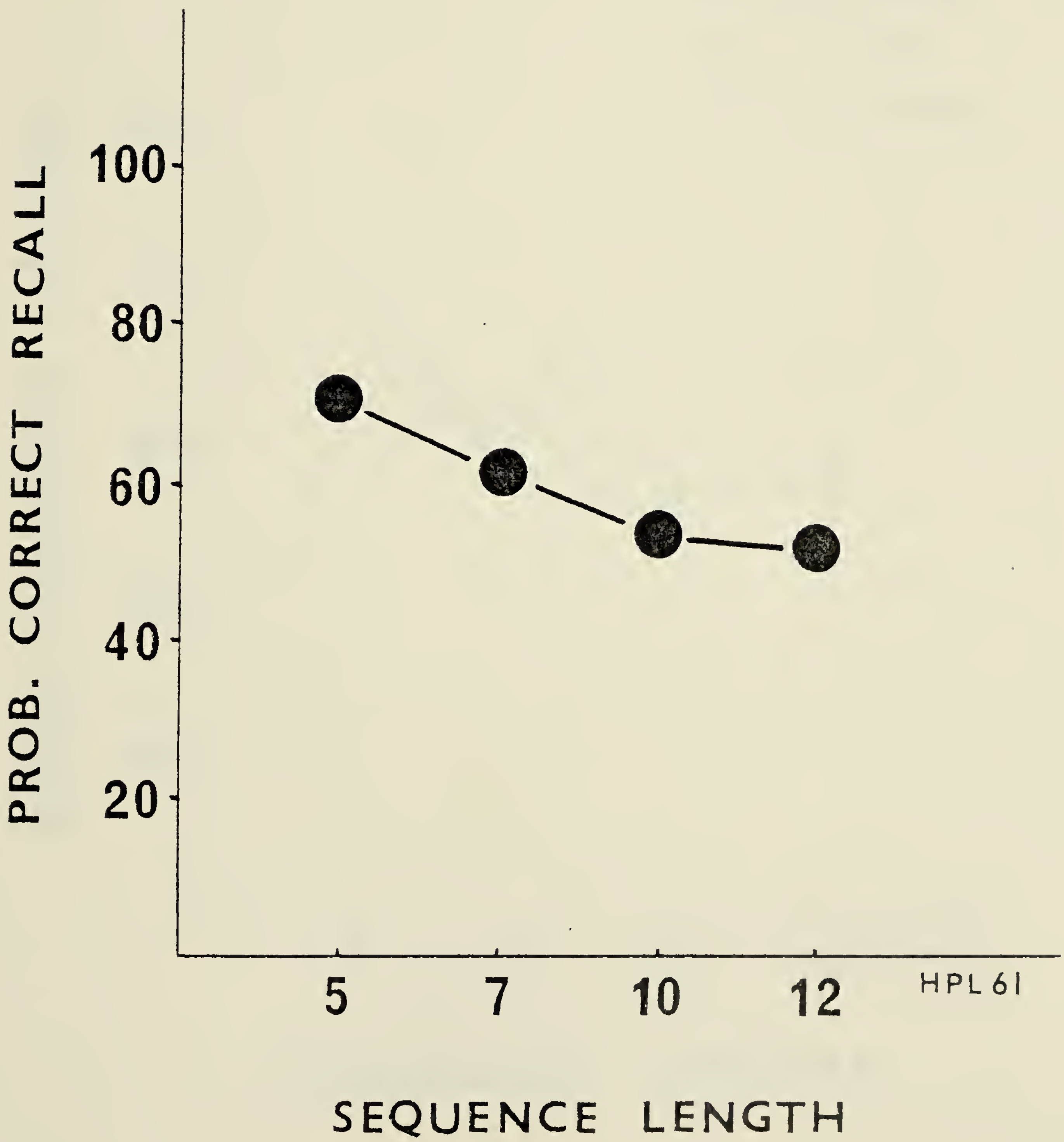


FIGURE 7

PERCENT CORRECT MOVEMENTS RECALLED

UNDER EACH SEQUENCE LENGTH CONDITION

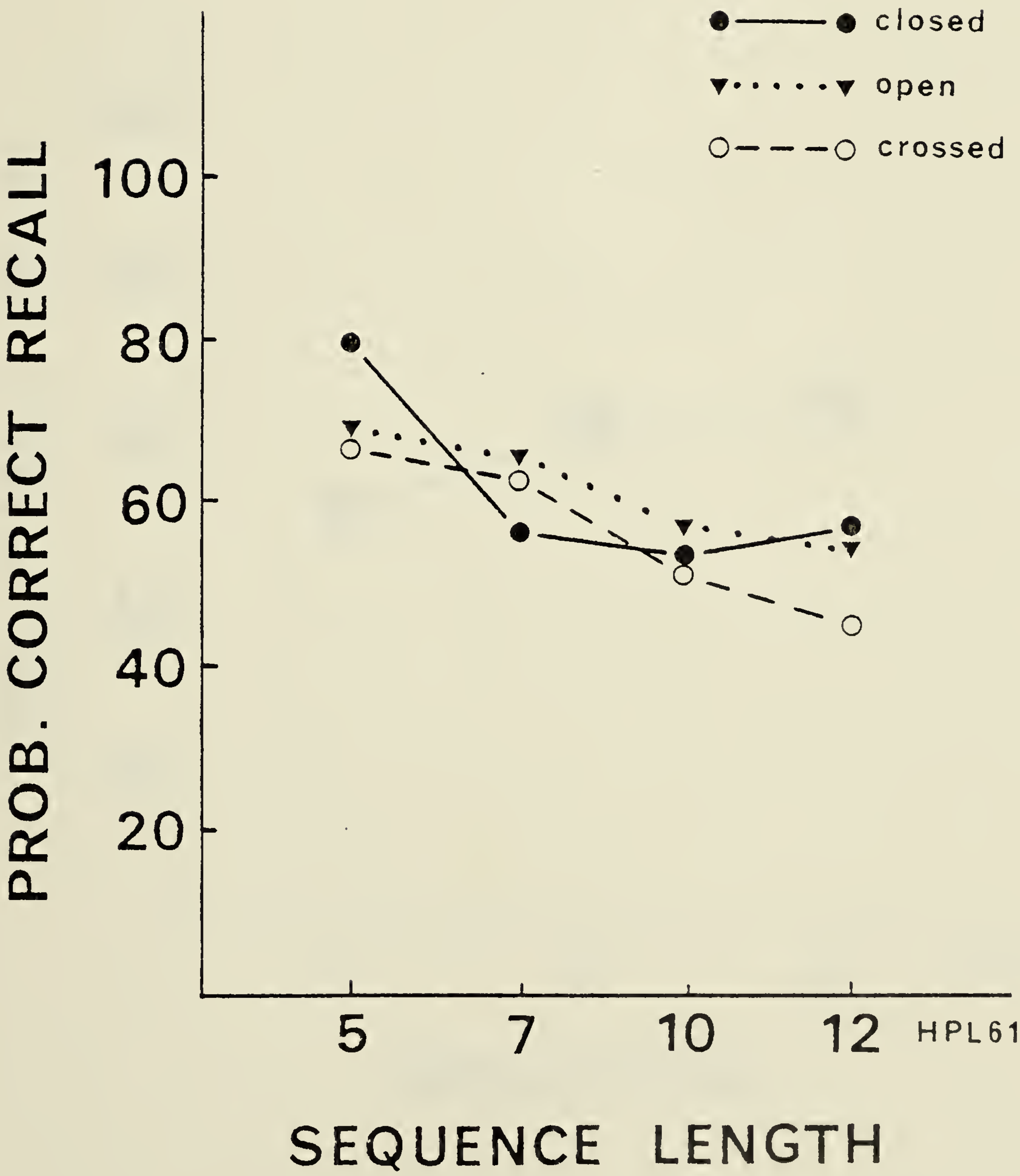


FIGURE 8

PERCENT CORRECT RECALL

FOR EACH REPLICATION

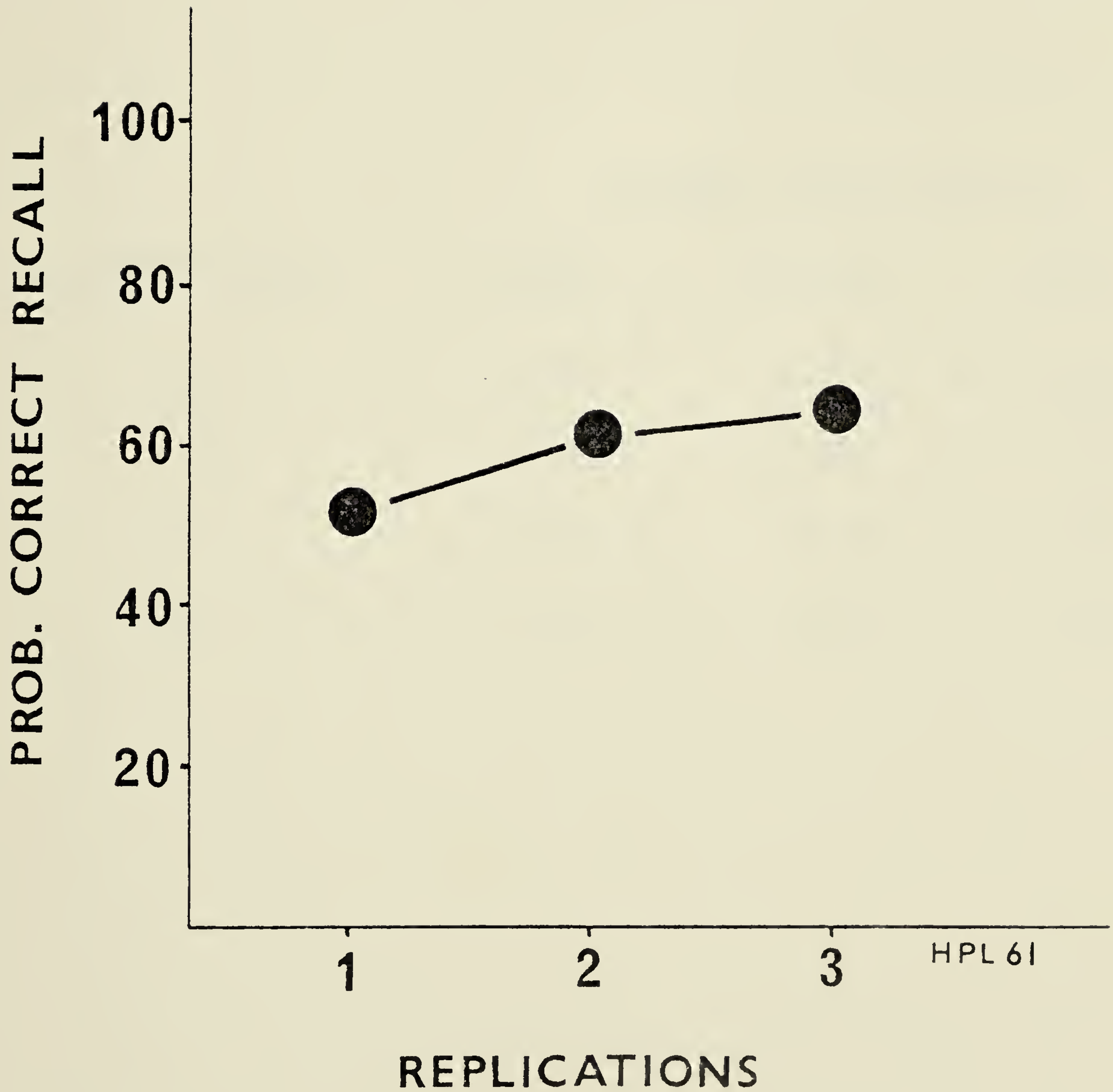


TABLE 2

MEAN RECALL

UNDER EACH MOVEMENT CHARACTERISTIC

AND SEQUENCE LENGTH CONDITION

	MOVEMENT CHARACTERISTIC		
SEQUENCE LENGTH	CLOSED	CROSSED	OPEN
5	1.583	1.350	1.358
7	1.112	1.302	1.290
10	1.058	1.033	1.129
12	1.124	0.902	1.099

The significant differences for the crossed movements were located between the sequences of 5 and 12, and 7 and 12 movements, at $p < .01$ (Figure 7, Table 2, Appendix B). Finally, there were no significant differences for the open movements, between the different sequence lengths, $p > .05$ (Figure 7, Table 2, Appendix B).

The significant differences for the replications were located by a Scheffé post hoc comparison test, between the replications 1 and 2, and 1 and 3, at $p < .001$ (Figure 8, Appendix B).

Finally, no serial position curves were found for the sequences of 5 and 7 movements, but clear serial position curves with primacy and recency effects are presented in Figures 9 and 10, for the sequences of 10 and 12 movements.

FIGURE 9

PERCENT CORRECT MOVEMENTS RECALLED

FOR EACH SERIAL POSITION

(Sequence length: 10)

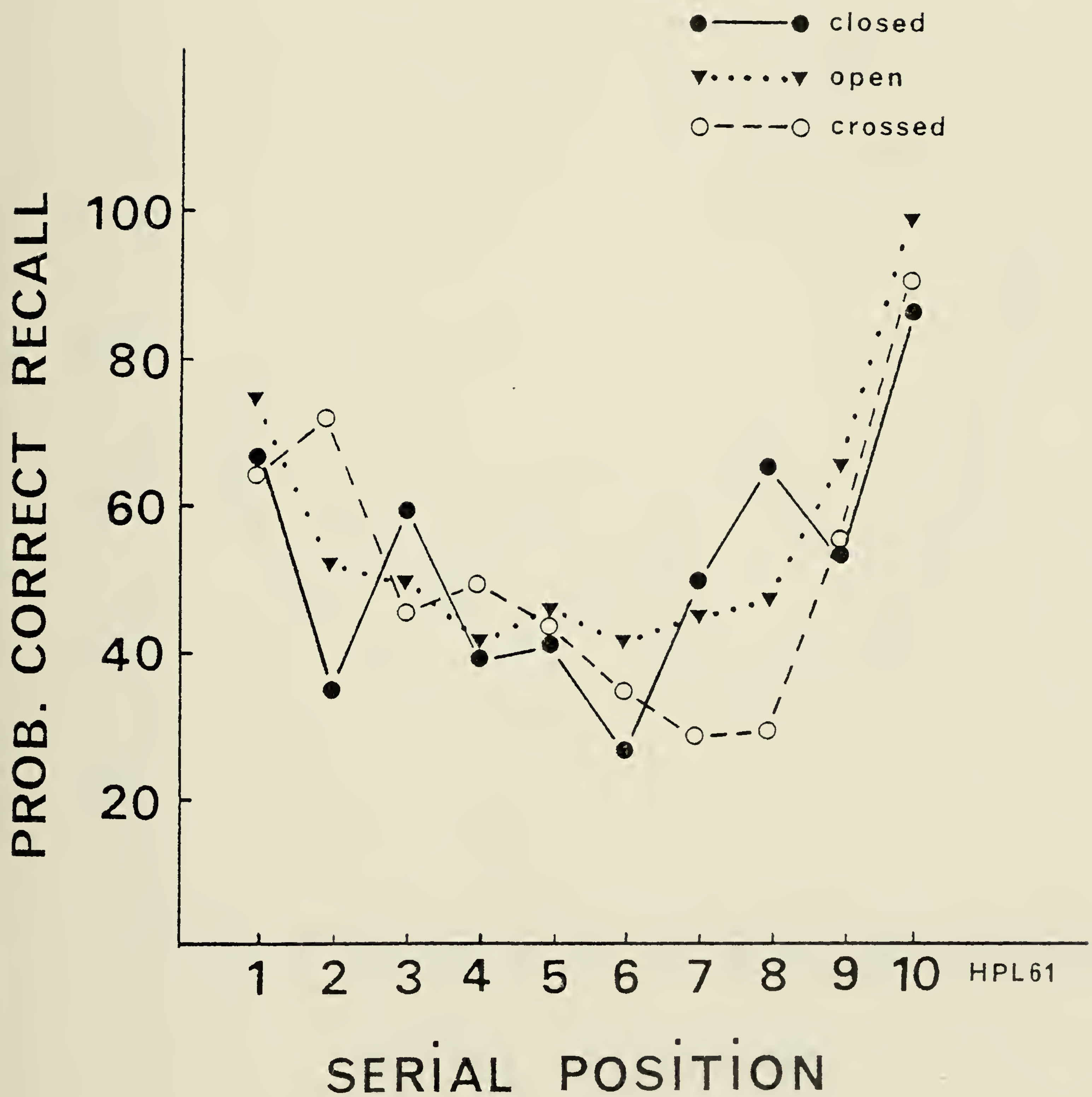
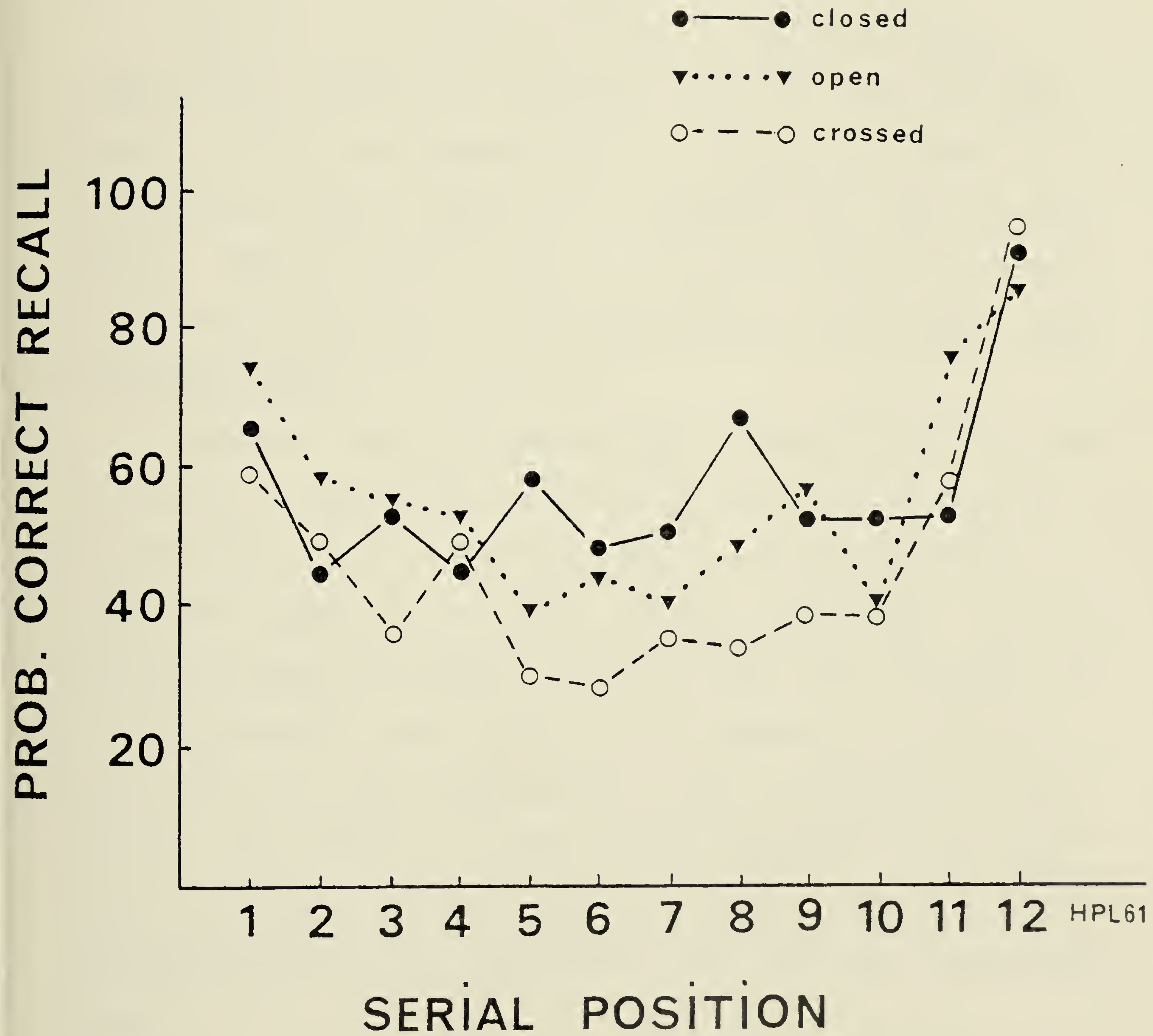


FIGURE 10

PERCENT CORRECT MOVEMENTS RECALLED

FOR EACH SERIAL POSITION

(Sequence length: 12)



Discussion

The results of this study demonstrated a clear SPC for the sequences of 10 and 12 movements (Figures 9, 10). As expected by Klatzky (1975) "the serial position effect holds true for lists of any length beyond the memory span" (p. 8).

Most of the authors in verbal literature found a significant decrease in retention as list length increase. However, this study demonstrated no significant decay for the open movements, between the sequences of 5 and 12 movements. Those findings suggest that the different movement characteristics were encoded differently, or at least, had different levels of retention.

However, the interaction effect produced by the closed movements, constitute an interesting point of discussion. As predicted by the studies in SPC in verbal literature, when list length is increased retention decreases. However, the percentage of correct recall of this study recorded for closed movements, was higher for the sequence of 12 movements than for the sequences of 7 and 10 movements. Those results are unusual in light of the literature, and suggest that the closed movements were recalled by using a different strategy than the one employed for the open and closed movements.

Since the Ss mentioned after the experiment that some sequences were drawing patterns and that they were trying

to remember the patterns described by the movements rather than the movements themselves, it could be hypothesized that the Ss tried to construct an internal image with the closed movements. If that was the case, the better recall observed for the sequences of 12 closed movements could be due to the particular characteristics of this pattern, which could has been easier to remember than the others.

Could we talk in terms of visual image ? (Sperling, 1963). Posner (1967) allowed the Ss to see their movements. Since the results demonstrated no forgetting after 20 seconds resting, Posner interpreted this finding as an evidence for movement information to be stored in the form of an image. Many of the Ss of the latter study reported that they were using imagery as a guide in retention and reproduction. More recently, Paivio (1974) assumed with various others, that "imagery includes a motor component, derived from perceptual exploration and manipulation of objects, which permits information to be transformed and reorganized within the system" (p. 4).

What do we know about the encoding of patterns of movements ? This question has no answer at the present moment, but further investigations should emphasize on the role of visual representation for the recall of kinesthetic bi-dimentional informations.

The results from Experiment 2 provided evidence that a SPC exists in motor memory, and hence that the Ss attempted to organize the to be remembered movement items into meaningful movement patterns.

In conclusion, Experiment 1 (Girard & Wilberg, 1977) and Experiment 2 (Wilberg & Girard, 1977) provide some support to suggest that movement items were encoded on the same basis of organizational rules, similar to those found in verbal experiments; the recall of order information (lists of movements) showed a clear primacy and recency effect. Finally, there was support to suggest that the Ss were recalling some of the order information by using associate information. In other words, when the movement items could be associated, the Ss grouped them together in order to recall one or several patterns.

There are a number of important variables which can be varied in the free recall paradigm. Each could provide important information about the nature of serial movement information stored in memory. Some of the more frequently used found in the free recall experiments of verbal items are: 1) rate of presentation (Murdock, 1962; Glanzer & Cunitz, 1966), 2) list length (Murdock, 1962; Postman & Phillips, 1965), 3) degree of associative relatedness between items (Glanzer & Schwartz, 1971), 4) frequency of the words (Raymond, 1969), 5) proactive interference (Goodwin, 1976), and 6) imagery (Paivio, 1974) and predictability (Holmes & Murray, 1974) of verbal items.

While all the above variables are important, and virtually no work has been performed on movement item lists, the variables relating meaningfulness, namely imagery and labelling, were chosen as the major focus in the following group of experiments.

As expressed by Sternberg (1969) the encoding process can involve the transformation of a nominal stimulus into some pictorial representation. This representation is generally termed an image and the fact of forming one; imagery. The naming process has been called labelling and its result, the production of a semantic label. Imagery is defined in the following experiments as an internal pictorial representation of the coming information (Paivio, 1971), and labelling as the naming of movement items (Shea, 1977).

The available research on imagery with regard to the distinction between primary and secondary memory shows consistently that imagery conditions facilitate secondary memory performance (Paivio, 1974). However, imagery seems not to be the only variable that improves secondary memory. For Brown (1976), 'label' provides accessibility to the image, and results in better retention. Holmes & Murray (1974) found that predictability affects recall from the secondary component of the SPC. In general high imagery and high predictability improved recall (Holmes & Murray, 1974). Considering the assumptions of Paivio (1974), Holmes & Murray (1974) and Brown (1976), this writer suggests that

'label' could render the coming informations more predictable and accessible, thereby producing a facilitation in the recall performance from the secondary component of the SPC.

A dual-coding hypothesis was postulated by Paivio (1971) and Paivio & Csapo (1973). Paivio (1974) recognized the importance of the imagery system in the transformation and reorganization of spatial information. The aformentioned presented the twin assumption of interconnectedness and independence of two distinct coding processes: the nonverbal imagery process and the verbal symbolic process. Interconnectedness of the two codes implies that one code can be transformed into the other; this means simply that pictures can be named and words can evoke nonverbal images. Independence implies that either one of the codes can be available and activated for recall. It also implies that the two codes can have additive effects on recall.

It was suggested by previous studies (Posner & Keele, 1968; Wilberg, 1969, 1970; Hall, 1977) that the code available for the retention of movement items would include such components as vision and kinesthesis and probably other unknown components. The investigator hypothesizes that imagery would be part of the visual component of the motor code and labelling an interconnected component of imagery. Shea (1977) recognized the importance of labelling upon motor retention. Therefore, the kinesthetic, visual, image and label components would form what can be called an 'integrated motor code'.

The purposes of Experiment 3 will be: 1) to determine if imagery and labelling are relevant strategies for the retention of movement information, and part of the motor code, 2) test the independence and interconnectedness assumption (Paivio & Csapo, 1973) of the image and label components of the motor code, and finally 3) look at the recall characteristics of order information, when imagery and labelling strategies are used.

The movement items presented to the Ss in this experiment were pre-organized by the investigator. The term pre-organization means that the movement items of each geometric figure in the list have been grouped together prior to presentation.

Experiment 3

The effects of image and label on the free recall of organized movement items

Method

Subjects

The subjects were eight volunteers, graduate students in Physical Education at the University of Alberta.

Apparatus and task

A joystick with a radius of 15 inches, could move in two dimensions within a circle of 12 inches diameter. The S while sitting, was able to move the joystick in all directions in the horizontal plane. His task consisted in the reproduction of movements within the region described by the apparatus.

The S and the E were activating an EICO auditory tone generator. The E was producing the signal tone for the presentation of movements and the S for the reproduction.

Design

The experimental design was a 3 x 2 x 5 factorial design with repeated measures on all factors. The first factor (Factor A) consisted of three levels of instructions: 1) a control condition (no strategy), 2) an imagery condition, and 3) an imagery + labelling condition. The second factor (Factor B) had two levels of retention: 1) an immediate, and 2) a final recall. The third factor (Factor C) consisted of five replications, under each experimental condition.

The order of presentation of the experimental conditions was identical across subjects. The presentation was in order: 1) control (no strategy), 2) imagery strategy, and 3) imagery-labelling strategy. It felt that image and label would be used as a strategy in the control condition, if the order of presentation was randomized.

Procedure

The experimentation was partitioned in four sessions, one session per day, each S being tested at the same time, each day. The first session consisted of a reading of the instructions by the E (Appendix A), several practice trials (number of practice trials determined by the S), and five experimental trials for an immediate recall condition. The second and third sessions, similar to the first, were preceeded by a recall of the movements given the day before (final recall condition). The fourth session consisted of a final recall only.

The S was seated and blindfolded for all experimental conditions including the reading of the instructions. The apparatus was located at the S's right or left side depending on his preferred hand. The emplacement of the chair could be changed to allow each S to move the joystick freely anywhere within its entire range.

Every movement in the list commenced with a starting point that was spatially different from the end-point of the preceeding movement. The following events constituted a

single trial. The S placed his hand on the handle of the joystick while the E, grasping lower on the stick, moved it for the S. A continuous tone sounded from the beginning to the end of the movement. The E then moved the lever to a new starting point from which the next movement in the list was to be made. That movement was not accompanied by a tone. The S had been instructed to remember only those movements which were paired with a tone in the sequence. A short burst of two tones, indicated to the S that he was to freely recall the lists of movements. He did so by moving the joystick himself, and indicating the recall of a movement item by pressing a switch which caused a tone. Only those movements he wished to be considered as one of the items from the movement list were paired with the tone. All others were considered irrelevant. The S could recall the lists of movements in any order he wished.

The rate of presentation was three seconds per movement, with three seconds required to move to a new starting point. There was no restriction of time for recall.

Data analysis

The data were recorded in terms of probability of correct recall (dependent variable) under each experimental condition (Figure 11) and in terms of probability of correct recall for each serial position in the list (Figures 12, 13). In order to record the data, the amount of admissible transformation was restricted to 22.5° either side of the expected

response (Figure 5).

An analysis of variance was calculated to determine if there were significant differences between the three levels of instructions, the two levels of recall, and the five replications. In cases of significance ($\underline{F}$ value) a Scheffé test on means was used.

For all statistical tests performed on the data, the criterion for rejecting the null hypothesis was $p < .01$.

Results

Significant differences between the three levels of instructions (C, I, I+L), $F(2,14) = 45.37$, $p < .001$, and between the two levels of recall (immediate and final), $F(1,7) = 29.72$, $p < .001$, were provided by the analysis of variance (Figure 11, Appendix B).

The results obtained from the Scheffé post hoc comparison test (Appendix B) revealed that all the levels of instructions were significantly different from each other, $p < .001$.

A levels of instructions x recall interaction effect was not apparent (Figure 11, Appendix B), $F(2,14) = 1.73$, $p > .05$, therefore the two recall conditions differed significantly from each other for each level of instruction.

Further, there were no significant differences between the five replications of each experimental condition, $F(4,28) = 2.99$, $p > .05$ (Appendix B).

The probabilities of correct recall are graphically presented under each recall condition (Figure 11) and under each serial position (Figures 12, 13).

FIGURE 11

PERCENT CORRECT RECALL

UNDER EACH RECALL CONDITION

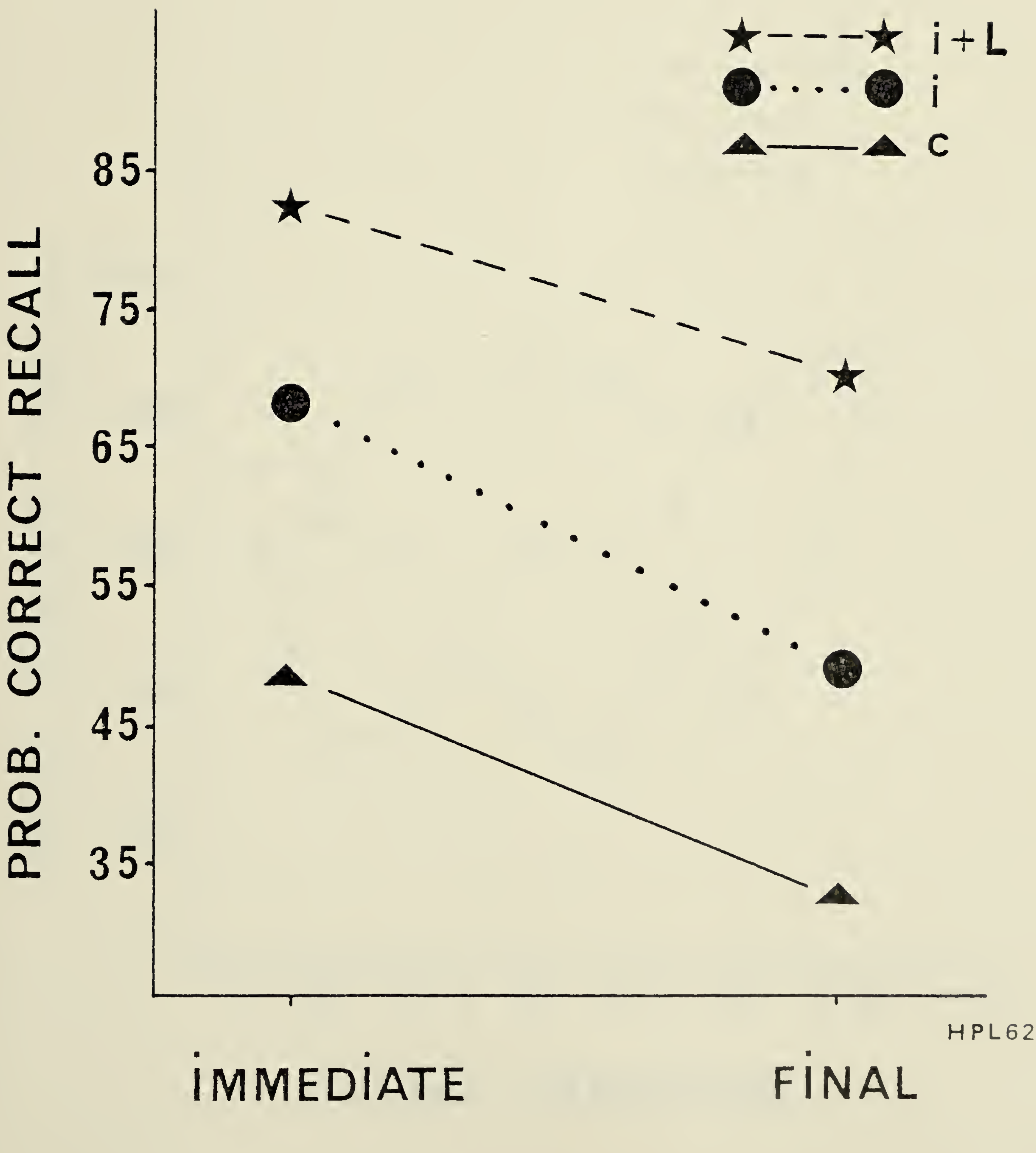


FIGURE 12

IMMEDIATE RECALL

UNDER EACH SERIAL POSITION

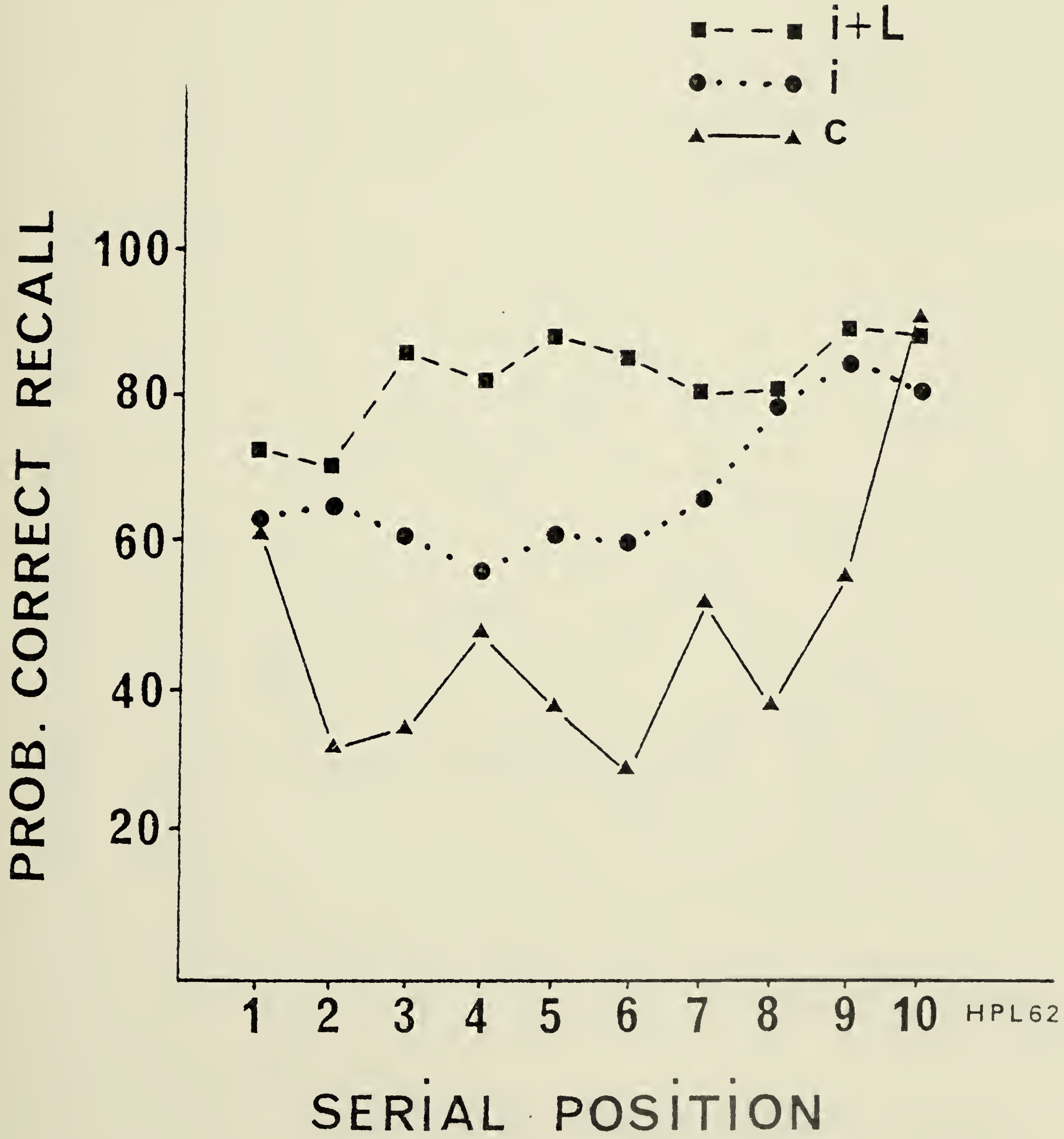
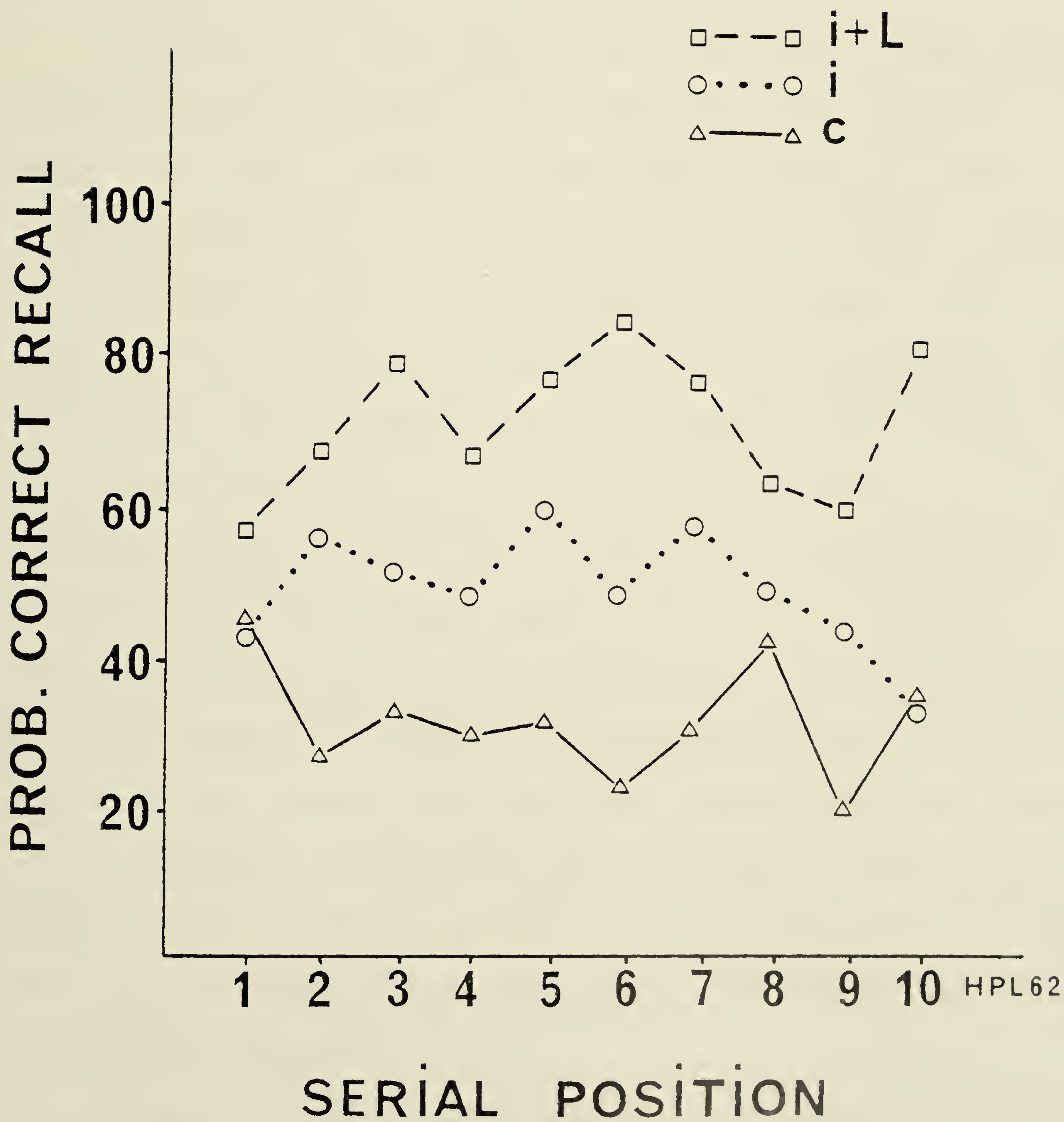


FIGURE 13

FINAL RECALL

UNDER EACH SERIAL POSITION



Discussion

Paivio's (1971) and Paivio & Csapo's (1973) assumption of independence, implying that image and verbal codes can have additive effects on recall, seems to be supported in this study. It is clearly demonstrated in Figure 11 and from the analysis (Appendix B) that the control (no strategy), imagery, and imagery+labelling conditions differ significantly from each other.

Suppose that in the control condition of this experiment only the kinesthetic (K) component was available for recall, in the I condition the K and I components were available and in the I+L condition the K, I, and L components were available. The results (Figure 11) would provide a support to the assumption that K, I, and L components are additive in their effects on motor memory. The results of this experiment (Figure 11) would be explained by Craik & Lockhart (1972) as the use of different orienting tasks (physically versus semantically oriented) and different degrees of activation of interconnected components, which may have varied the depth of processing of the coming information. The control group may have used a physical encoding of the movement information and the others (I and I+L) a semantic one, whereas probably the I+L condition provided the deepest encoding, and the largest activation of interconnected components.

Daniel (1972) would suggest that in the I condition

of this experiment Ss could have provided their own labels to the stimulus patterns. Therefore, the main difference between the recall performances from the I and I+L conditions would not be due to the availability of one (I) or two (I+L) components of the motor code, but would be a result of predictability or unpredictability provided by the label (I+L) or no label (I) condition (Holmes & Murray, 1974). The latter authors obtained the highest recall from a high predictable and high imagery condition.

Shea (1977) who provided relevant verbal labels with movement items at the presentation of criterion position, observed the lowest error score for the relevant verbal label group and no significant forgetting after 60 seconds for the same group. His suggestion supports the results of the I+L condition of this study to say that the use of a relevant verbal label aid in the remembering of a motor response and can be a valuable mnemonic strategy which leads to increased accuracy at recall.

The results of this study also support Paivio's (1971) and Paivio & Csapo's (1973) assumption of interconnectedness, implying that words can evoke nonverbal images. An extensive look at the raw data permits one to assert that the labels provided in the I+L condition of this experiment, evoked for all the subjects their related nonverbal images. For all lists of movements, when the labels were provided the Ss demonstrated a facility to give back the movements, chunked (Miller, 1956) by geometric figures.

Other interesting points of discussion are brought by the results of the SPC. Firstly, the results of a clear SPC for the control condition (no strategy) at the immediate recall (Figure 12), support the preceeding findings of Wilberg & Girard (1977) that a SPC exists in motor memory. Secondly, the graphical evidence (Figure 12) that imagery benefited recall from all parts of the SPC, contradicts Holmes & Murray's (1974) and Paivio's (1974) findings. The higher recall of all serial positions suggests that the movement information accompanied with an imagery strategy were processed at a conceptual level. Thirdly, the highest recall of the I+L condition suggests that the label gave more accessibility to the image (Brown, 1976). Finally, the results of the SPC provide evidence that in both the I and the I+L conditions the movement information were processed at a conceptual (Paivio, 1974) or semantic level (Craik & Lockhart, 1972).

Experiment 3 provided evidence for the superiority of imagery and labelling strategies upon the free recall of movement items, and a facilitation in the recall performance of all parts of the SPC. It was suggested that image and label are independent, but interconnected components of the motor code activated at varying degrees, and both necessary to the encoding, retention, and retrieval of order movement information.

This last experiment (Experiment 3) provided evidence that the use of both imagery and labelling produce a superiority in recall accuracy when the movement information is organized at time of presentation. The next experiment (Experiment 4) was designed to investigate the strength of relevant verbal labels upon motor memory, by presenting the Ss with movement information in a completely randomized order. The S's task was to organize the patterns of movements in memory when given various labels.

Experiment 4

The effects of image and label on the free recall of randomized movement items

Method

Subjects

The subjects were eight volunteers graduate students in Physical Education at the University of Alberta.

Apparatus and task

A joystick with a radius of 15 inches, could move in two dimensions within a circle of 12 inches diameter. The S while sitting, was able to move the joystick in all directions in the horizontal plane. His task consisted in the reproduction of series of movements within the region described by the apparatus.

The S and the E were activating an EICO auditory tone generator. The E was producing the signal tone for the presentation of movements and the S for the reproduction.

Design

The experimental design was a 2 x 2 x 5 factorial design with repeated measures on all factors. The first factor (Factor A) consisted of two levels of instructions: 1) a control condition (no strategy), and 2) an imagery + labelling condition. The second factor (Factor B) had two levels of retention: 1) an immediate and, 2) a final recall. The third factor (Factor C) consisted of five replications under each experimental condition.

Procedure

The experimentation was partitioned in three sessions, one session per day, each subject being tested at the same time, each day. The first session consisted of a reading of the instructions by the E (Appendix A), several practice trials (number of practice trials determined by the S), and five experimental trials for an immediate recall condition. The second session, similar to the first, was preceeded by a recall of the movements given the day before (final recall condition). The third session consisted of a final recall only.

The procedure is similar to the one used in Experiment 3, whereas extensive procedural explanations are provided (see procedure, Experiment 3).

Data analysis

The data were recorded in terms of probability of correct recall (dependent variable) under each experimental condition (Figure 14) and in terms of probability of correct recall for each serial position in the list (Figures 15, 16). In order to record the data, the amount of admissible transformation was restricted to 22.5° either side of the expected response (Figure 5).

An analysis of variance was calculated to determine if there were significant differences between the two levels of instructions, the two levels of recall, and the five replications. A test on means was not necessary since there

were only two levels of each factor and since no interaction effect was found.

For all statistical tests performed on the data, the criterion for rejecting the null hypothesis was $p < .01$.

Results

Significant differences between the two levels of instructions (C and I+L) were provided by the analysis of variance, $F(1,7) = 44.04$, $p < .001$ (Appendix B). However, no significant differences were found from the same analysis, between the two levels of recall (immediate and final), $F(1,7) = 0.81$, $p > .05$.

There was no levels of instructions x recall interaction effect (Figure 14), $F(1,7) = 3.05$, $p > .05$. Therefore, the two levels of instructions differed significantly from each other under each recall condition.

Finally, no significant differences were found between the five replications performed by all <u>S</u>s under each experimental condition, $F(4,28) = 1.32$, $p > .05$ (Appendix B).

The probabilities of correct recall are graphically presented under each recall condition (Figure 14) and under each serial position (Figures 15, 16).

FIGURE 14

PERCENT CORRECT RECALL

UNDER EACH RECALL CONDITION

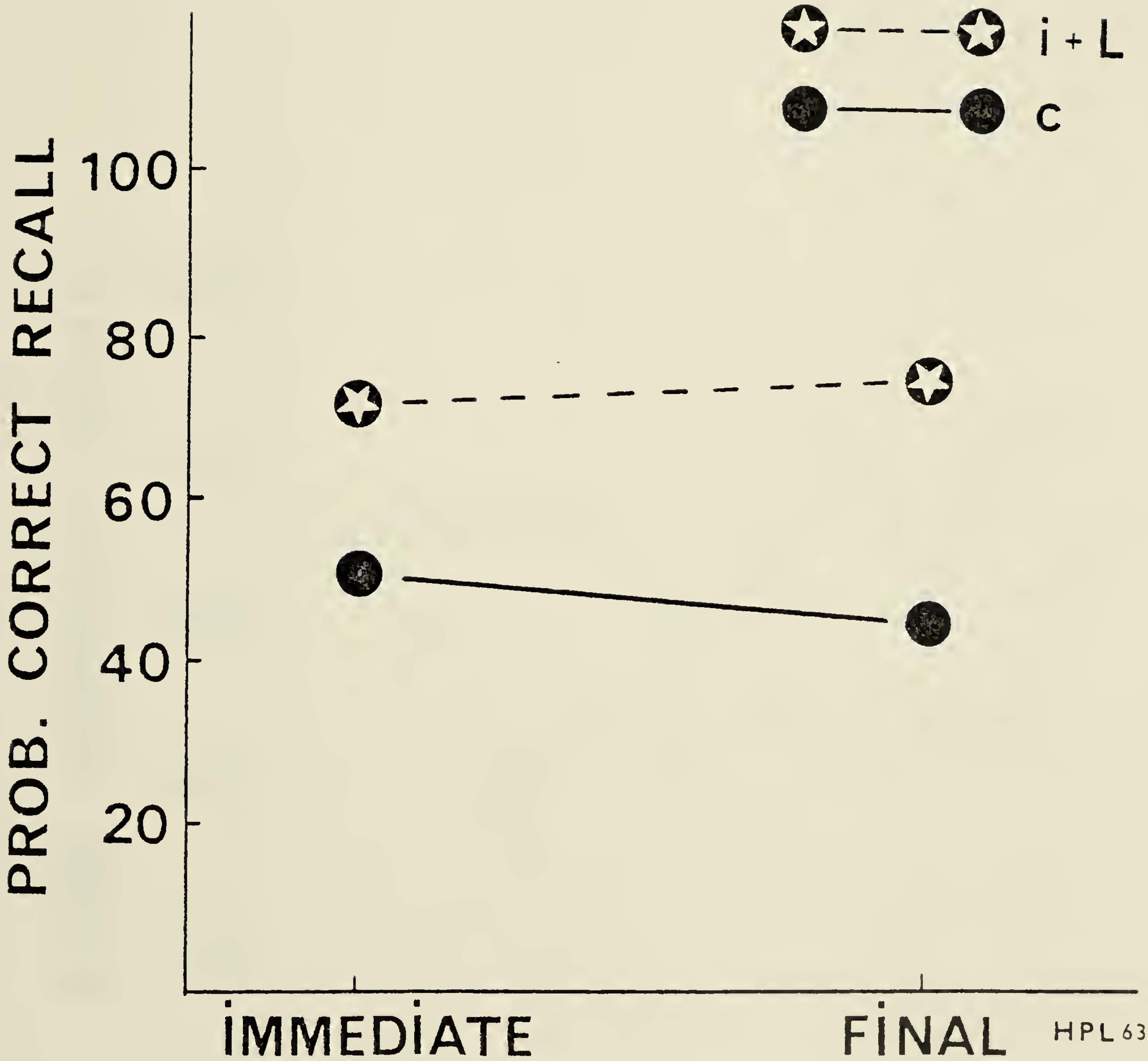


FIGURE 15

IMMEDIATE RECALL

UNDER EACH SERIAL POSITION

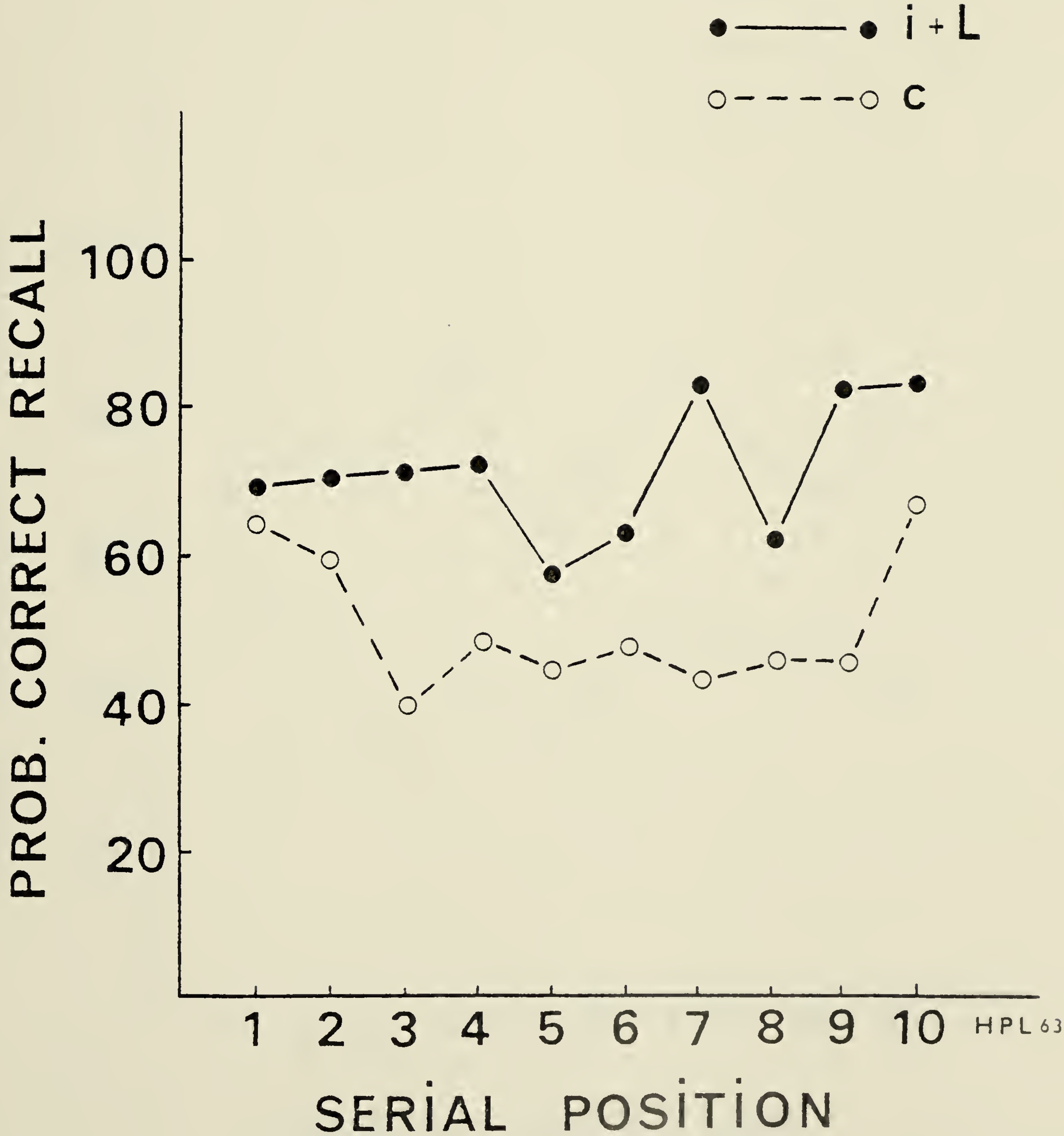
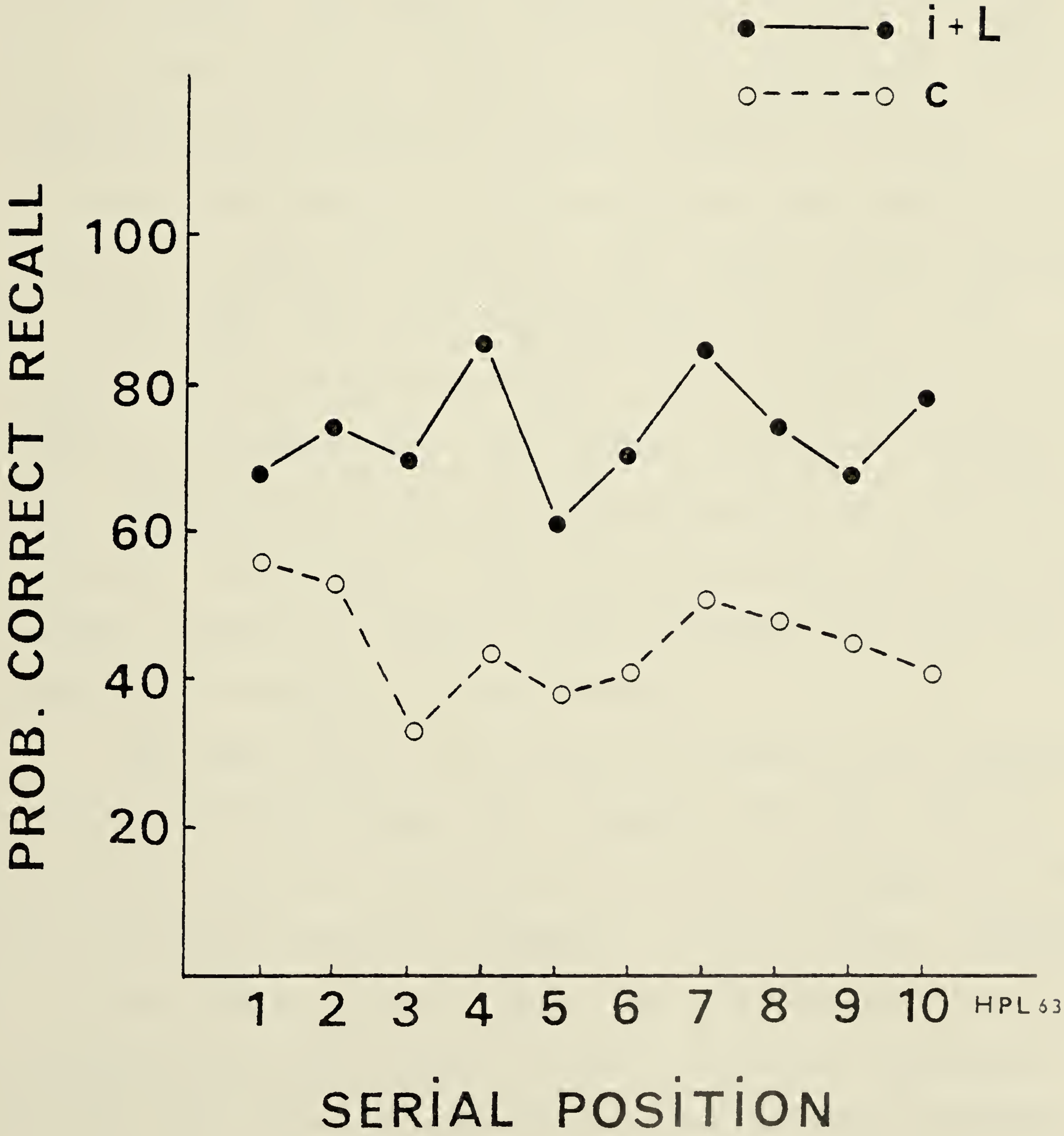


FIGURE 16

FINAL RECALL

UNDER EACH SERIAL POSITION



Discussion

The significant differences between the two levels of instructions (C and I+L) (Figure 14), $F(1,7) = 44.04$, p .001, support the results of Shea (1977), and provide evidence that imagery and labelling can be important variables in the retention of movement information. Although no significant loss of retention was expected for the I+L group, the results demonstrating a gain of information after 24 hours (Figure 14) were surprising. This suggests that a cognitive process related to the S's strategy, was capable of maintaining and even improving the recovery of items from memory. The control group indicated no significant loss of retention after 24 hours. This suggests that the Ss were using a special strategy to remember the movements. The assumption receives support from comments of the Ss in a debriefing session following the last, final recall. They indicated that they were using imagery, either by trying to make a pattern with the movements, or by using the clock analogy.

The lack of SPC for the control group at the immediate recall condition (Figure 15), suggests that the personal strategies used by this group, disturbed the shape of a SPC. The failure of the SPC to appear in the I+L group, suggests a similar effect. These suggestions are supported by evidence that a SPC occurs in motor retention (Wilberg & Girard, 1977) when Ss are unable to mediate the movements.

The similarities of the curves at the immediate and final recall (Figures 15, 16), indicate that the informations were remembered as well after 24 hours, as they were when immediate recall was required.

This study therefore provides evidence that imagery and labelling are two variables that should be investigated in the subsequent experiments, since they appear to be part of the visual component of the motor code. In this study as in earlier ones, labelling was not removed from imagery and imagery from labelling. It seems logical to think that one component implies the other; but, since neither imagery nor labelling have been investigated separately, probably because of their high level of meaningfulness, it is not evident if the improvement in performance was due to imagery and labelling together, or if it was due to labelling only. Answering that problem will constitute the major point of following investigations.

Experiment 4 confirmed the findings of Experiment 3. The use of an integrated imagery-labelling strategy improved significantly the recall performance even when the movement information were presented in a completely randomized order.

However, the findings of Experiments 3 and 4 hold true only if the results of these experiments are entirely due to the experimental variables, and not to some other variable such as an order effect. In Experiments 3 and 4, the order of presentation of the instructional strategies was not varied across subjects. It felt that image and label would be used as a strategy in the control condition. In the following experiment (Experiment 5) two different orders of presentation of the instructional strategies were used, to determine if there was any order effect in the preceeding experiments. Experiment 5 was identical to Experiment 3, the exception being that the order of presentation of the instructional strategies has been varied. Whereas in Experiment 3, the order was: 1) C (no strategy), 2) I, and 3) I+L, the two orders of presentation used in Experiment 5 were first: 1) I, 2) I+L, and 3) C; and second: 1) I+L, 2) C, and 3) I, in order for each instructional strategy to happen in each of the three positions.

Experiment 5

A further investigation
into the effects of image and label
on the free recall of organized movement items

Method

Subjects

Sixteen volunteers, graduate and undergraduate students in Physical Education at the University of Alberta, accepted to participate in the experiment. This group was partitioned in two groups of eight subjects; each group was assigned to one order of presentation of the instructional strategies.

Apparatus and task

A joystick with a radius of 15 inches, could move in two dimensions within a circle of 12 inches diameter. The S while sitting was able to move the joystick in all directions in the horizontal plane. His task consisted in the reproduction of series of movements within the region described by the apparatus.

The S and the E were activating an EICO auditory tone generator. The E was producing the signal tone during the presentation and the S for the reproduction.

Design

Two experimental designs have been considered in this study. The first design was a 3 x 2 x 5 factorial with repeated measures on all factors, and the same subjects across experimental conditions. This design was used for each of the two orders of presentation of the instructional strategies. The first factor (Factor A) consisted of three

levels of instructions: a) a control (no strategy), b) an imagery strategy, and c) an integrated imagery-labelling strategy. The second factor (Factor B) had two levels of recall: a) an immediate recall, and b) a final recall. The third factor (Factor C) consisted of five replications, under each experimental condition.

The second design was a factorial 3 x 3 x 2 with repeated measures on the last two factors, and different subjects across the different orders of presentation. The first factor (Factor A) had three orders of presentation of the instructional strategies; the first order being: a) C, b) I, c) I+L; the second order: a) I, b) I+L, c) C; and the third order: a) I+L, b) C, c) I. The second factor consisted of three levels of instructions: 1) control (no strategy), 2) imagery, and 3) imagery+labelling. The third factor had two levels of recall: 1) an immediate recall, and 2) a final recall.

Procedure

Partitioning of the sessions remained the same as well as the procedure of Experiment 3.

Data analysis

The data were recorded in terms of probability of correct recall (dependent variable) under each experimental condition and each serial position in the list (Figures 17, 18, 19, 20, 21, 22). The amount of admissible transformation

was restricted to 22.5° either side of the expected response (Figure 5).

Three analyses of variance have been calculated to determine if there were significant differences between the three orders of presentation of the instructional strategies, the three levels of instructions, and the two levels of recall. First, two three way analyses of variance with the same Ss across conditions (see first design) were calculated for each order of presentation used in Experiment 5; and second, a three way analysis of variance was calculated with different Ss across the different orders of presentation of the instructional strategies (see second design). In cases of significance (F value) a Scheffé test on means was used.

For all statistical tests performed on the data, the criterion for rejecting the null hypothesis was $p < .01$.

Results

The results section will be divided in three parts. The first part will concern the analysis calculated for the second order of presentation of the instructional strategies (I+L, C, I), whereas the first order (C, I, I+L) consisted in Experiment 3; the second part will concern the third order of presentation of the instructional strategies (I, I+L, C); and the third part will concern the three orders of presentation (Experiments 3, 5) included in the same analysis.

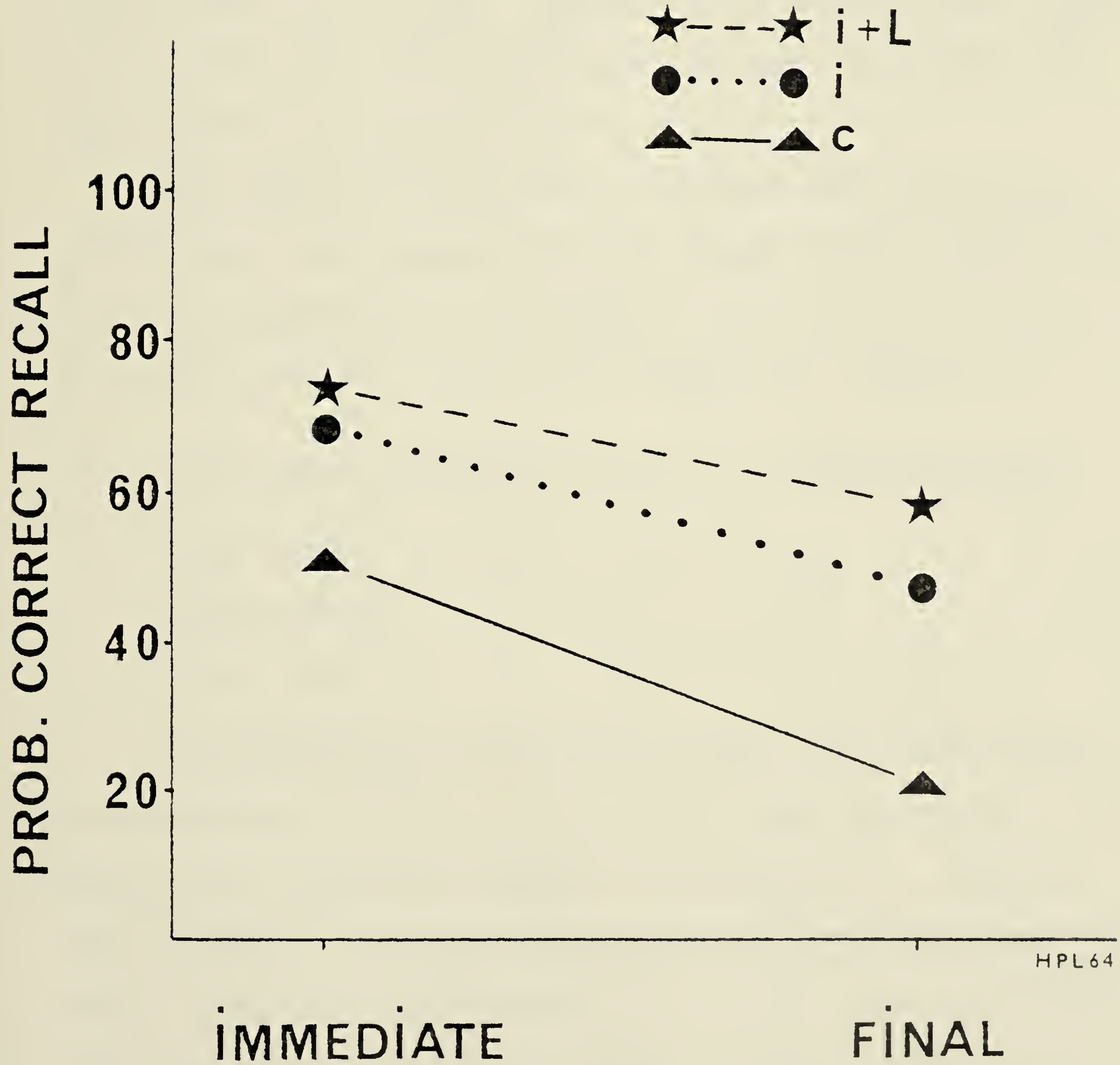
Second order of presentation (I+L, C, I)

Significant differences between the three levels of instructions (I+L, C, I), $F(2,14)= 47.04$, $p < .001$, and between the two levels of recall (immediate and final) $F(1,7)= 17.42$, $p < .005$, were provided by the analysis of variance (Figure 17, Appendix B). There were no significant interaction effects, and no significant differences between the five replications of the same Ss under each experimental condition, $p > .05$.

Scheffé was used for post hoc comparisons and revealed that the significant differences for the instructional strategies, were located between C and I, and C and I+L, at $p < .001$, whereas I and I+L did not differ significantly, $p > .05$.

FIGURE 17

PERCENT CORRECT RECALL :
SECOND ORDER OF PRESENTATION
OF THE INSTRUCTIONAL STRATEGIES
(I+L, C, I)



Third order of presentation (I, I+L, C)

Significant differences between the three levels of instructions (I, I+L, C), $F(2,14) = 8.09$, $p < .005$, and between the two levels of recall (immediate and final) $F(1,7) = 123.48$, $p < .001$, were provided by the analysis of variance (Figure 18, Appendix B). The levels of instructions x recall interaction effect, $F(2,14) = 5.32$ was significant at $p < .025$. There were no significant differences between the five replications of the same Ss under each experimental condition, $p > .05$.

The conservative Scheffé test was used for post hoc comparisons and revealed that the significant differences for the instructional strategies, were located between C and I+L, and I and I+L, at $p < .01$ (Figure 18, Appendix B).

The three orders of presentation in the same analysis

First order:	C	I	I+L
Second order:	I+L	C	I
Third order:	I	I+L	C

No significant differences between the three orders of presentation, $F(2,21) = 3.65$, $p = .043$, were provided by the analysis of variance (Figure 19, Appendix B). However, the same analysis provided significant differences between the three levels of instructions (C, I, I+L), $F(2,42) = 80.92$, $p < .001$, the two levels of recall (immediate and final), $F(1,21) = 97.16$, $p < .001$ (Figure 20, Appendix B), and a significant order x levels of instructions interaction effect,

FIGURE 18

PERCENT CORRECT RECALL :

THIRD ORDER OF PRESENTATION

OF THE INSTRUCTIONAL STRATEGIES

(I, I+L, C)

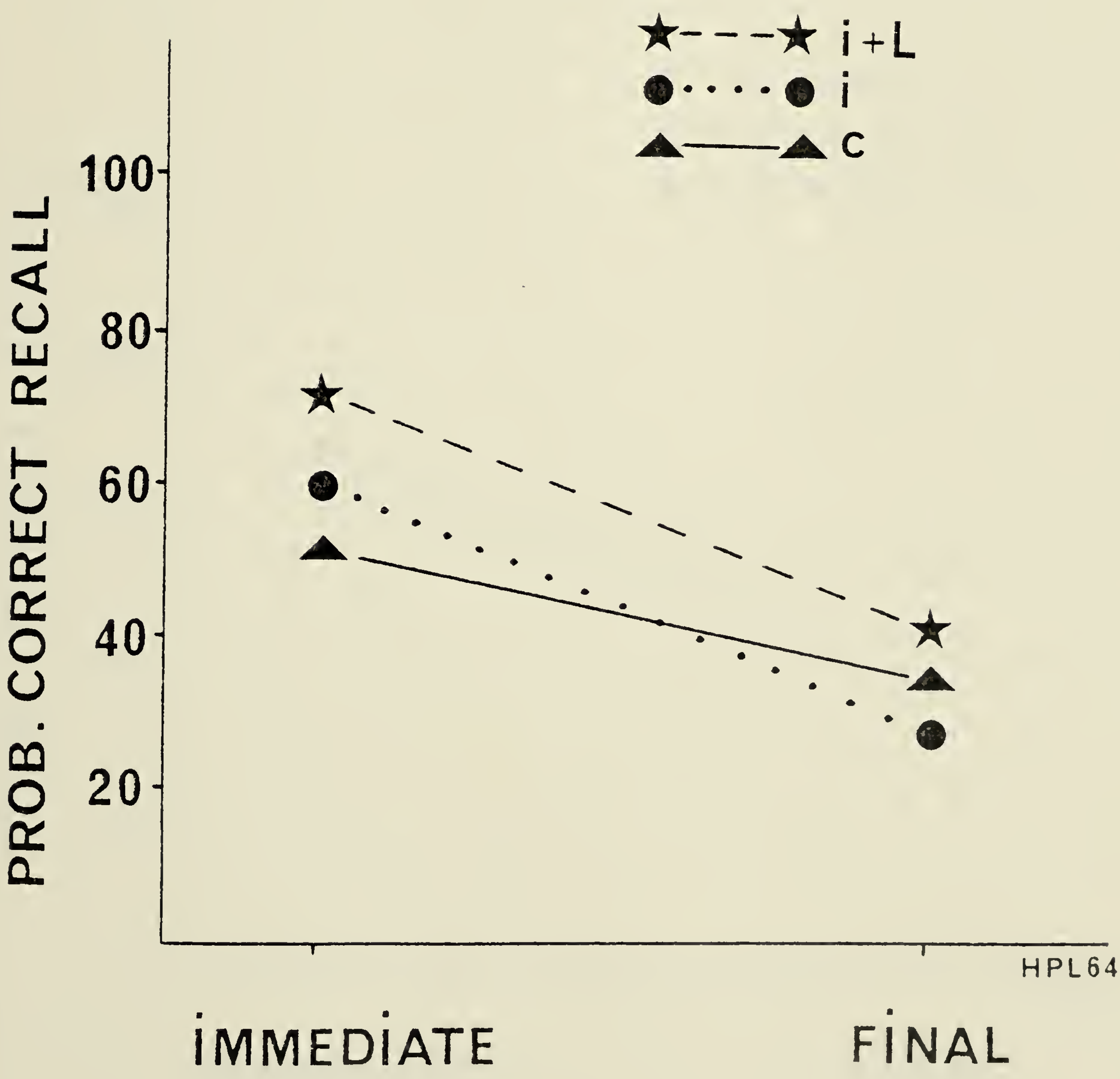


FIGURE 19

PERCENT CORRECT RECALL :

INSTRUCTIONAL STRATEGIES

COLLAPSED WITHIN ORDERS OF PRESENTATION

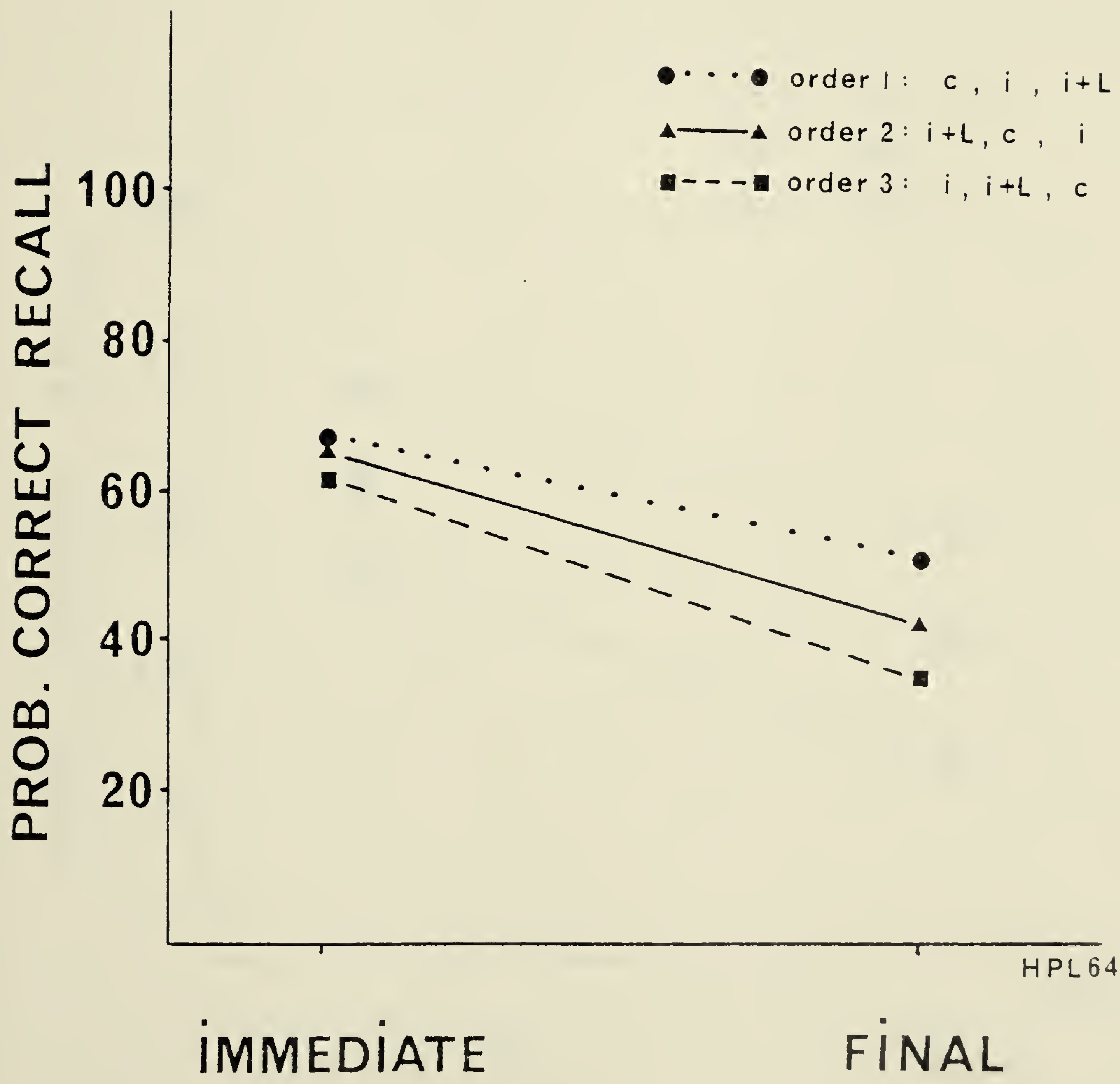
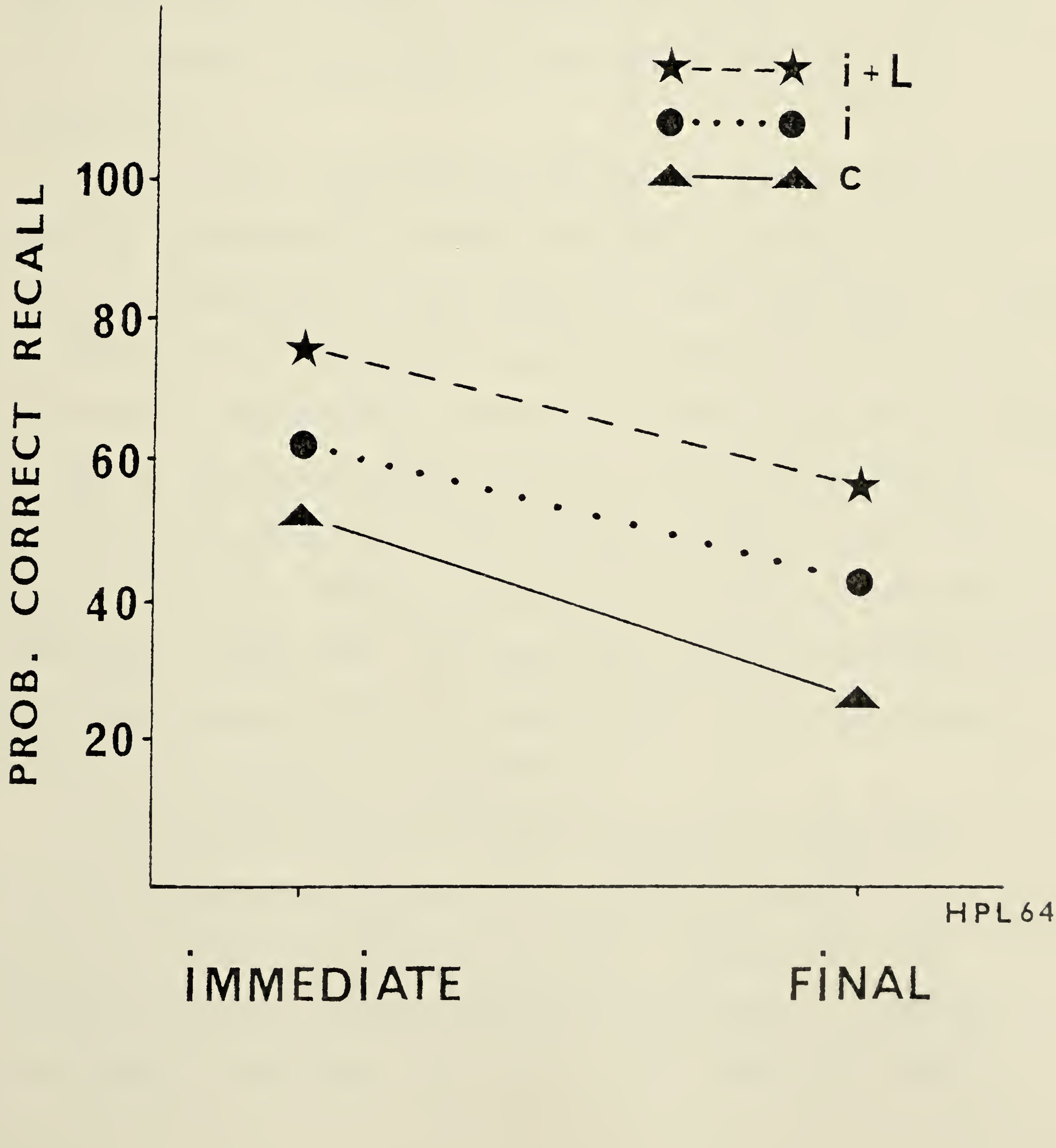


FIGURE 20

PERCENT CORRECT RECALL :

ORDERS OF PRESENTATION

COLLAPSED WITHIN INSTRUCTIONAL STRATEGIES



$F(4,42) = 8.38$, $p < .001$ (Appendix B).

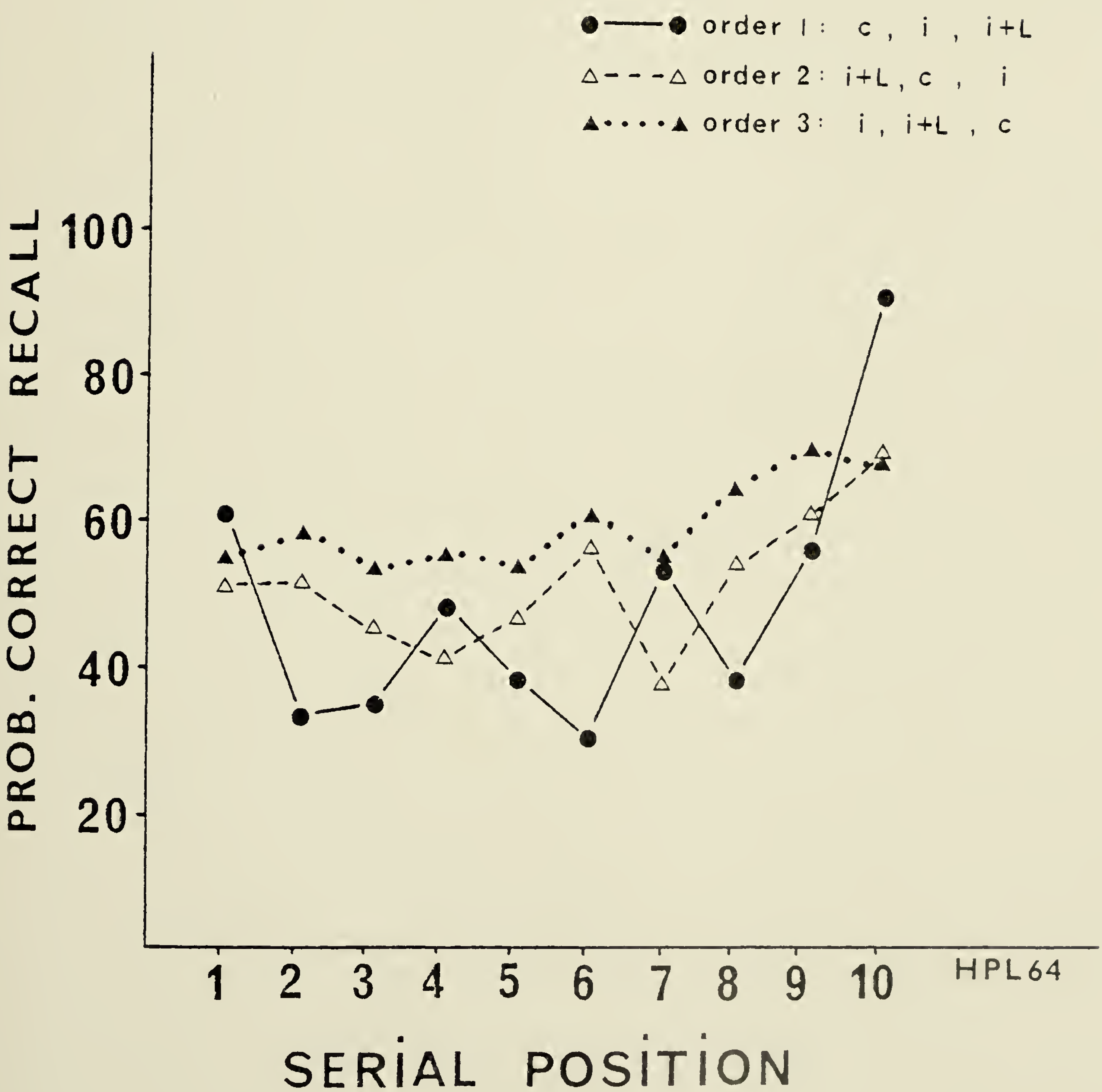
Scheffé test on means was used for post hoc comparisons and revealed that all the levels of instructions (C, I, I+L) were significantly different from each other, $p < .001$ (Figure 20, Appendix B). The Scheffé test was also used for the order x levels of instructions interaction effect. It revealed that for the first and second order of presentation the levels of instructions were significantly different from each other, whereas for the third order C, I, and I+L did not differ significantly from each other, $p > .01$ (Figure 18).

The lack of significant differences found for the third order of presentation between the three levels of instructions, is clarified by the results of the same order x levels of instructions interaction effect. This last interaction provided no significant differences between the three control groups of the three orders ($p > .01$), and no significant differences between the three imagery groups of the three orders ($p > .01$). The only exception to this finding was the labelling groups; the first and third orders of presentation for these groups, differed significantly from each other, $p < .01$ (AB interaction, Appendix B).

The probabilities of correct recall for the three control groups on the immediate recall are graphically presented under each serial position (Figure 21). The probabilities of correct recall for the control, imagery, and imagery+labelling conditions on the immediate recall

FIGURE 21

IMMEDIATE RECALL
FOR EACH ORDER OF PRESENTATION
OF THE INSTRUCTIONAL STRATEGIES
(CONTROL GROUPS)



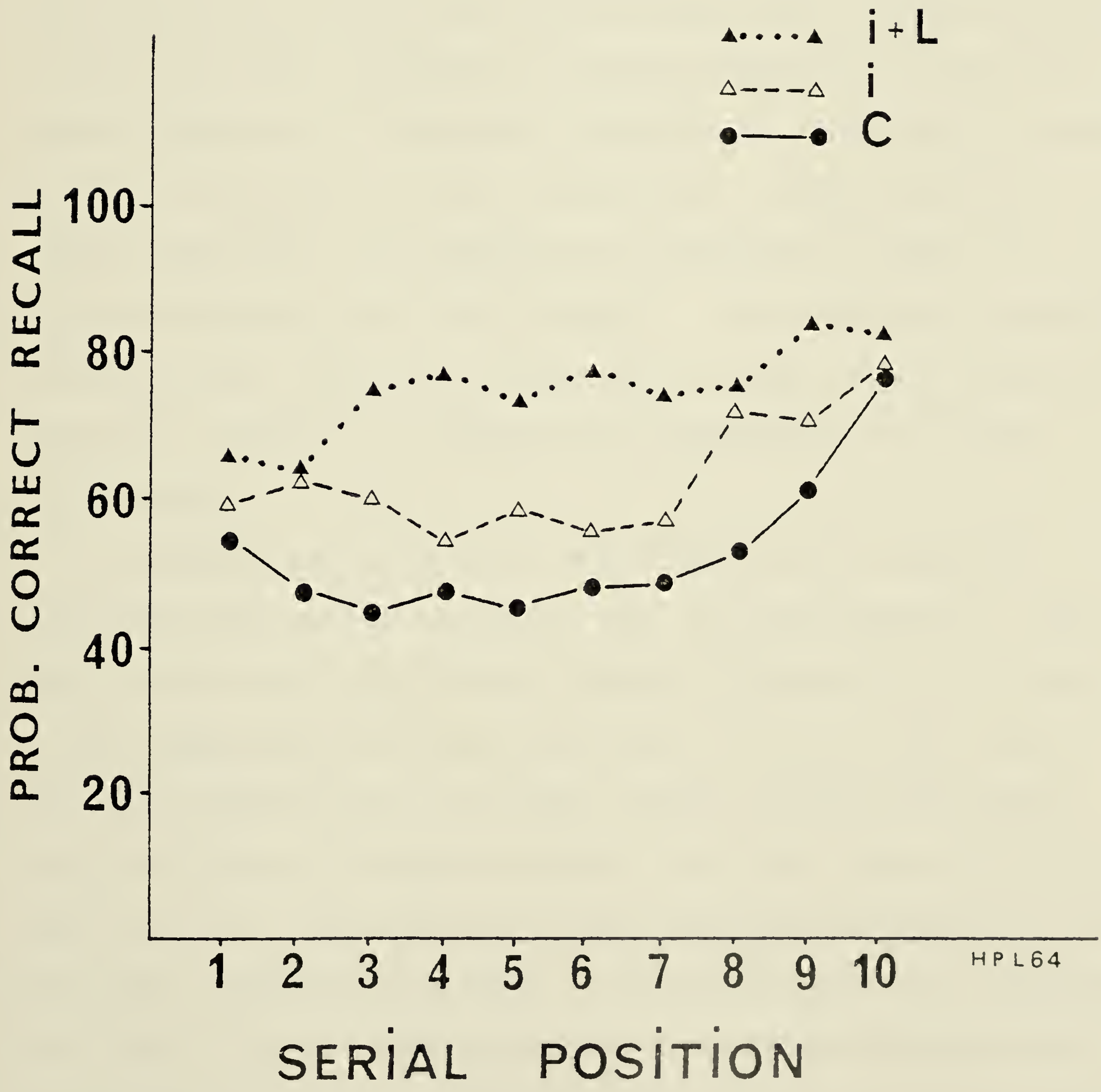
(three orders collapsed) are presented under each serial position (Figure 22).

FIGURE 22

IMMEDIATE RECALL :

ORDERS OF PRESENTATION

COLLAPSED WITHIN INSTRUCTIONAL STRATEGIES



Discussion

If we consider the analysis of variance calculated for each order of presentation of the instructional strategies; the analysis of the first order (Appendix B) indicated that the three conditions (C,I,I+L) differed significantly from each other at $p < .001$ (Figure 11), the analysis of the second order of presentation (Appendix B) indicated some significant differences only between C,I and C,I+L at $p < .001$ (Figure 17) and the analysis of the third order (Appendix B) indicated significant differences between C,I+L and I,I+L at $p < .025$ (Figure 18). These results demonstrate that the significant differences change in probabilities as the order changes. The graphical representation of the three control groups in terms of their serial position (Figure 21) suggests one explanation for those differences.

A serial position curve was found for the control group who was tested the first day of experimentation, and not for the two other control groups (Figure 21). In light of the preceding findings (Wilberg & Girard, 1977), the results suggest that the control groups tested the second and third days of experimentation, who were told not to use any strategy, did in fact use the strategies proposed by the E in the preceding sessions. A table of the mean immediate and final recalls (ABC interaction, Appendix B) demonstrate a progressive better immediate recall for the control groups

tested the first day ($\overline{X}$= 0.967), the second day ($\overline{X}$= 1.025), and the third day ($\overline{X}$= 1.19) of experimentation. The raw data also provide the certainty that the subjects of these control groups were using partly or completely the strategies proposed in the imagery and imagery+labelling conditions, since the subjects of these groups were recalling the sequences of movements by chunking (Miller, 1956) the movement items in geometric figures. It seems, therefore, impossible to ask a subject not to use a strategy, when that subject used that strategy in a previous session. The high performances of these control groups did certainly contribute to the low probability (p= .043) found between the three different orders of presentation, calculated by the analysis of variance (Appendix B).

The major findings of this study, calculated by the analysis of variance including the three orders of presentation, were the highly significant differences between all the instructional strategies (C,I,I+L), at $p < .001$ (B main effect, Appendix B). However, a significant order x instructional strategies interaction effect indicated that these differences could be dependent upon the orders of presentation. The results of this last interaction effect were mainly the same ones found with the independent analysis of variance calculated for each order of presentation; the most significant differences were found for the first order of presentation, where the three strategy conditions differed significantly from each other. Less significant differences

were found for the second order of presentation, and the least significant differences were found for the third order of presentation.

One may think from the previous results, that the order of presentation had some type of effect on recall. However, the results of the order x instructional strategies x recall interaction effect (Appendix B) indicated no significant differences at the immediate recall, between the three control groups ($\overline{X}_1$= .967, $\overline{X}_2$= 1.025, $\overline{X}_3$= 1.19), the three imagery groups ($\overline{X}_1$= 1.362, $\overline{X}_2$= 1.38, $\overline{X}_3$= 1.03), and the three imagery+labelling groups ($\overline{X}_1$= 1.64, $\overline{X}_2$= 1.477, $\overline{X}_3$= 1.417), and no significant differences at the final recall, between the three control groups ($\overline{X}_1$= .647, $\overline{X}_2$= .43, $\overline{X}_3$= .55), the three imagery groups ($\overline{X}_1$= .977, $\overline{X}_2$= .957, $\overline{X}_3$= .695), and two of the three imagery+labelling groups ($\overline{X}_2$= 1.16, $\overline{X}_3$= .825). The only exception was the significant differences found at the final recall condition between the imagery+labelling groups of the first ($\overline{X}_1$= 1.41) and third order of presentation ($\overline{X}_3$= .825) (ABC interaction, Appendix B). It was concluded from those results that there were no significant order effects.

From all the preceeding findings some major points can be expressed. The control, imagery, and imagery+labelling groups (Experiments 3 and 5) present, in the order they are mentioned, a significant improvement in recall performances (Figures 11, 17, 18, 20). It seems therefore, that these results support the assumption of additivity of image and label (Paivio, 1971; Paivio & Csapo, 1973) components of the

motor code. The raw data also suggest that for all subjects, the labels evoked their representative mental images and hence support partly the assumption of interconnectedness of images and labels (Paivio & Csapo, 1973). Finally, the collapsed results of the control groups (Figure 22) support a serial position effect when no strategy is used. The imagery and imagery+labelling strategies (I,I+L) actively improved the recall of all the movement items, regardless of their position in the list (Figure 22).

These findings suggest that movement information is perhaps being semantically processed (Craik & Lockhart, 1972) or processed at a conceptual level (Paivio, 1974).

Since no experimental order effects were significant, a series of two experiments was proposed to investigate the assumptions of interconnectedness and independence of image and label upon motor memory. These investigations were necessary to determine the nature of the motor code.

From the results of Experiments 3, 4, and 5, it is evident that the Ss could represent internal images when given verbal labels. However, it is not evident if inversely, Ss can produce some verbal labels given the representative internal images. It was the first concern of Experiment 6 to determine if internal images evoke their verbal associates. The second purpose was to establish a scale of meaningfulness for movement patterns; and the third one, to determine if the movement patterns presented in Experiments 3, 4, and 5, were high or low meaningful (M) patterns. Since the movement patterns were grouped for reproduction in Experiments 3, 4, and 5, it was concluded that they could be high M. This experiment was designed to determine if they were, as expected previously, highly M for the Ss. Consequently, the movement patterns will be considered high M if the Ss can label them. And if it is the case, the complete assumption of interconnectedness of image and label components of the motor code will be true. We will have the certainty that series of movements elicit representative internal images, which ones evoke their verbal associates.

The second purpose of Experiment 6, to establish a

scale of meaningfulness for movement patterns, constitute a compulsory step to test the assumption of independence of image and label. More extensive details will be provided later. This scale of meaningfulness will permit to constitute for Experiment 7, five lists having the same characteristics as the lists presented in Experiments 3, 4, and 5, the exception being that the movement patterns will be low M.

Therefore, the 13 geometric figures given in Experiments 3, 4, and 5, and 39 random patterns, making a total of 52 movement patterns, were presented to the Ss to determine their degree of meaningfulness. The 39 movement patterns were determined randomly with restrictions upon the number of figures having 2, 3, 4, 5, 6, and 8 sides. In Experiments 3, 4, and 5, the 13 geometric figures were distributed as follow: (3) 2 sided figures (X's); (3) 3 sided figures (triangles); (4) 4 sided figures (square, diamond, rectangles); (1) 5 sided figure (pentagon); (1) 6 sided figure (hexagon); and (1) 8 sided figure (octogon).

It was decided that the number of random patterns for each category (2 sided, 3 sided, etc.) would be tripled, in order to have the certainty of getting at least the 13 low M movement patterns needed for Experiment 7. Therefore, the number of random patterns for each category was distributed as follow: (9) 2 sided figures; (9) 3 sided figures; (12) 4 sided figures; (3) 5 sided figures; (3) 6 sided figures; and (3) 8 sided figures.

The scale of meaningfulness was determined so that for high M movement patterns Ss could not attach any label to them; for less M movement patterns Ss could not attach any label, but the patterns reminded them something that they knew; and for low M movement patterns Ss could not attach any label nor say that the patterns reminded them something. For this last case, the patterns were totally released of significance (see Instructions, Appendix A).

Experiment 6

Scale of meaningfulness
for movement patterns

Method

Subjects

Fifty volunteers, undergraduate students in Physical Education at the University of Alberta, participated in the following experiment.

Apparatus and task

A joystick with a radius of 15 inches could move in two dimensions within a circle of 12 inches in diameter. The S, while placed in a sitting position, could grasp the joystick that the E was moving for him in all locations in the horizontal plane.

The S's task consisted to make associations with the movement patterns described for him by the E, and his previous knowledges. The S had to take one of the following three choices after each movement pattern was described kinesthetically by the E : 1) attach a verbal label to the movement pattern if possible, 2) say 'yes' if no label could be attached, but the movement pattern reminded him of something, or 3) say 'no' if the movement pattern was not reminding him of anything.

Design

The experimental design was a treatments x subjects design. The two experimental treatments consisted of the two levels of meaningfulness of the movement patterns: 1) the expected high M geometric figures presented in Experiments

3, 4, and 5, and 2) the low M patterns of this experiment.

The order of presentation of the 52 movement patterns was counterbalanced and independently determined for each one of the 50 subjects.

Procedure

Each S was individually tested in a single session of approximately 60 minutes. The S was seated and blindfolded throughout the experiment; including the reading of the instructions. The apparatus was located at the S's left or right side, depending on his prefered hand, in such a way that he could move the joystick freely anywhere within its entire range. The instructions which were read to the subjects appear in Appendix A. The Ss received 52 different movement patterns throughout a single session experiment.

Data analysis

The data were recorded on an ordinal basis in order to determine the degree of meaningfulness of each movement pattern. The number of 'no', 'yes', and 'label' responses to each of the 52 movement patterns are reported on Tables 3, 4, and 5.

The statistical analyses consisted of two *t* tests. The first *t* test was calculated between the number of label responses of the 13 geometric figures presented in Experiments 3, 4, and 5, and the 39 random patterns of this experiment. The second *t* test was calculated between the number of label

responses of the 13 geometric figures presented in Experiments 3, 4, and 5, and the 13 lowest meaningful random patterns of this experiment. The lowest meaningful random patterns were those which had the fewest number of label responses.

The criterion for rejecting the null hypothesis was $p < .01$.

Results

Two analyses were performed on the data. First, a *t* test between the level of meaningfulness (number of label responses) of the 13 geometric figures and the 39 random patterns (first analysis); second, a *t* test between the level of meaningfulness of the 13 geometric figures and 13 low M random patterns.

First analysis

Significant differences, $t = 13.03$, $d.f. = 50$, $p < .001$, were found between the level of meaningfulness of the 13 geometric figures and the 39 random patterns.

Second analysis

In the second *t* test, significant differences were also found between the level of meaningfulness of the 13 geometric figures and the 13 lowest meaningful movement patterns, $t = 15.08$, $d.f. = 24$, $p < .001$.

The graphical representation of the 52 movement patterns are given in Figures 23, 24, 25, 26, and 27. The number of 'label', 'yes', and 'no' responses to the 52 movement patterns are presented in Tables 3, 4, and 5. Finally, the distribution of meaningfulness value for the 52 movement patterns is presented in Figure 28.

FIGURE 23

GEOMETRIC FIGURES

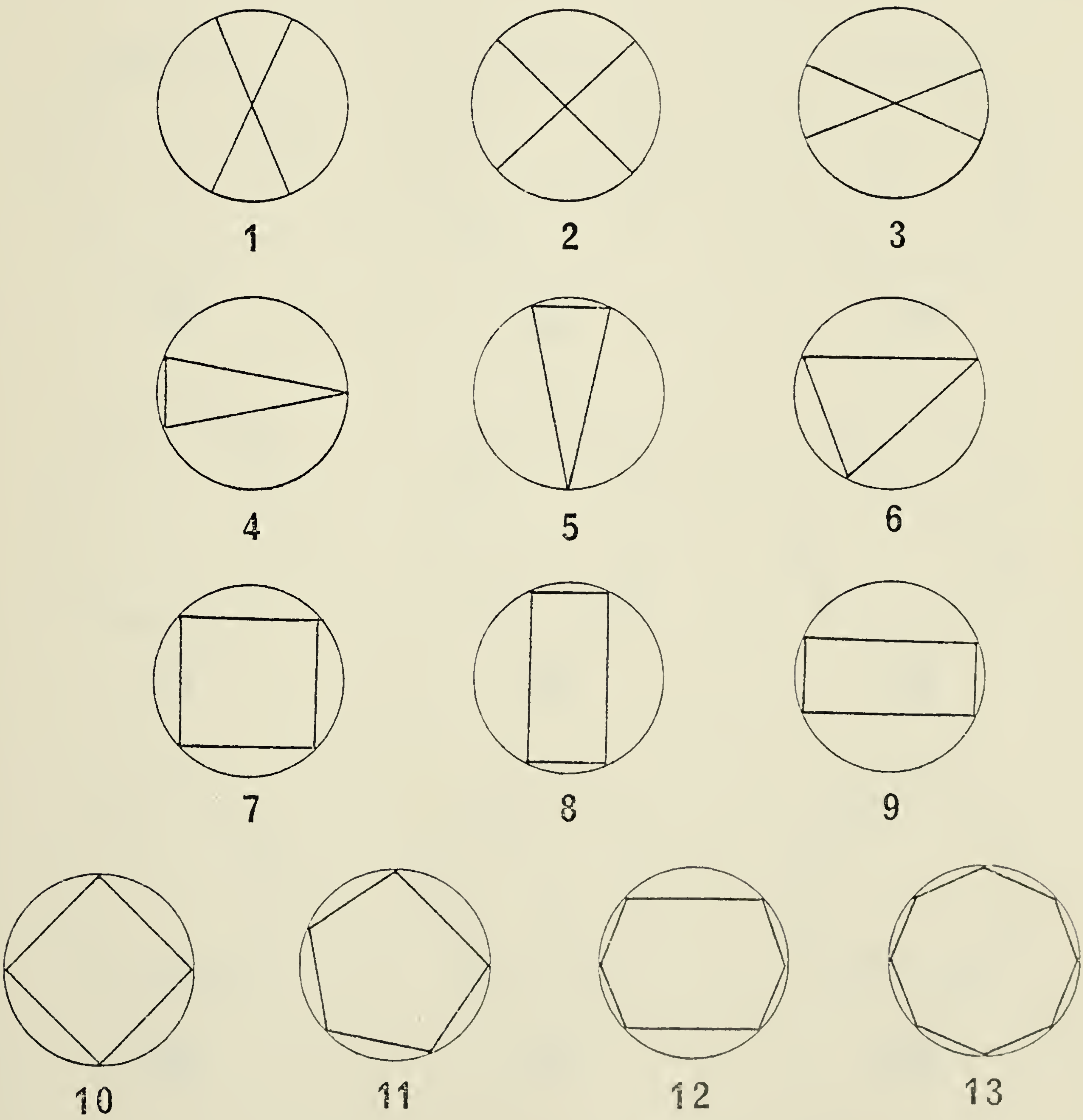
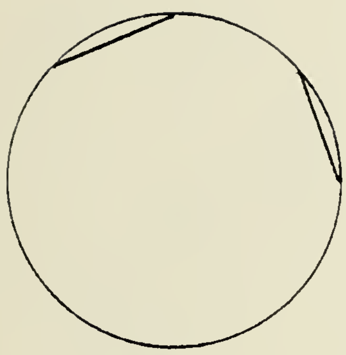


FIGURE 24

TWO SIDED RANDOM PATTERNS



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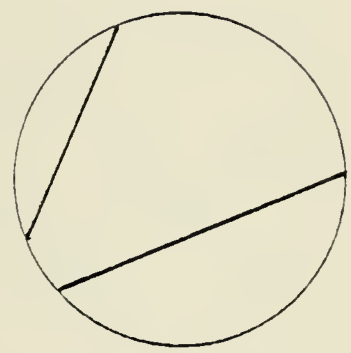

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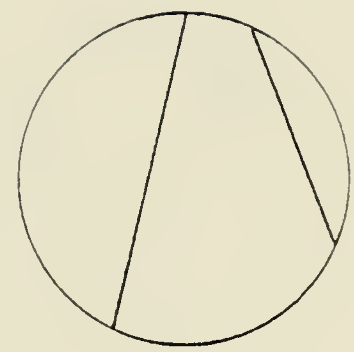

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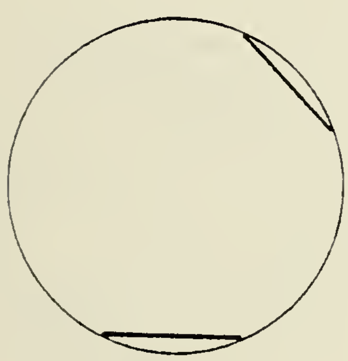

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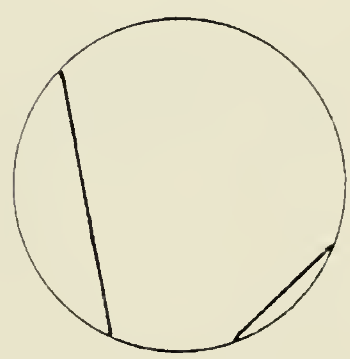

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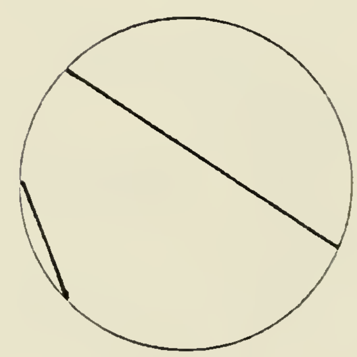

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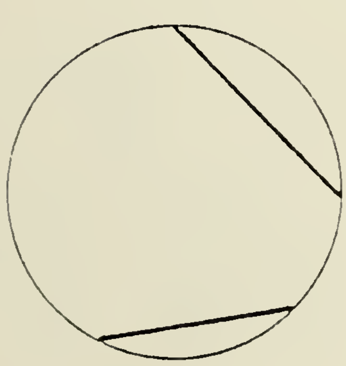

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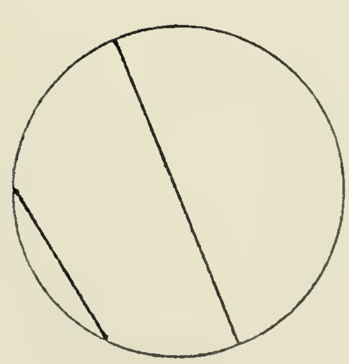

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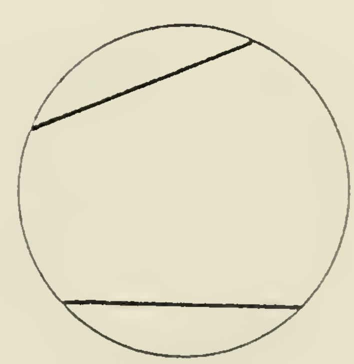

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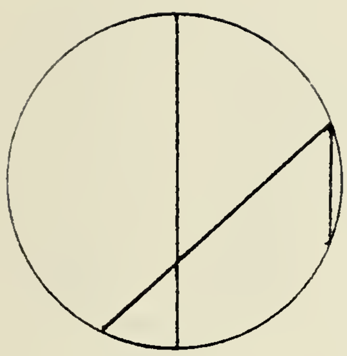
FIGURE 25

THREE SIDED RANDOM PATTERNS



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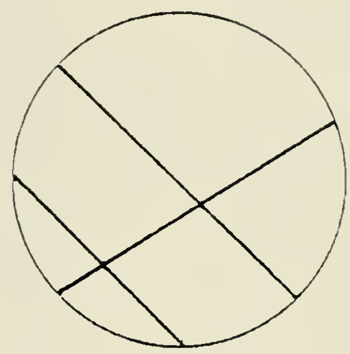

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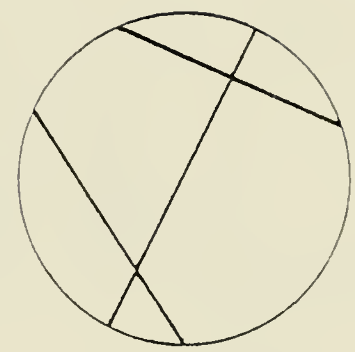

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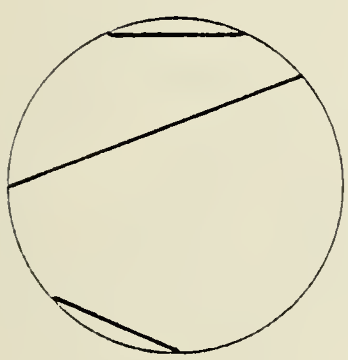

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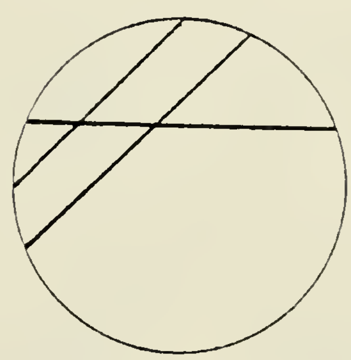

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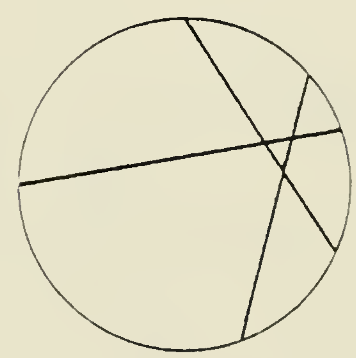

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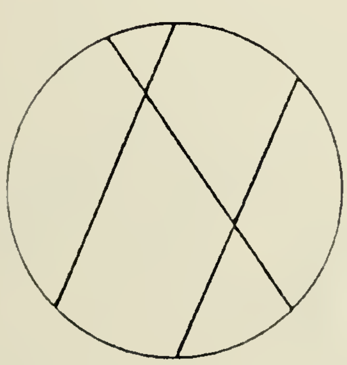

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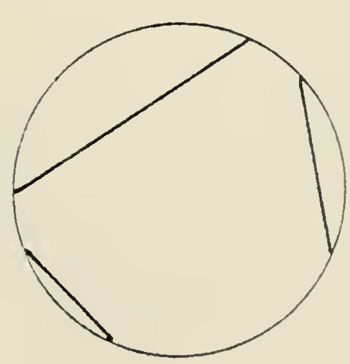

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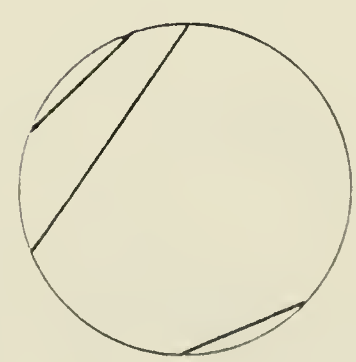

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FIGURE 26

FOUR SIDED RANDOM PATTERNS

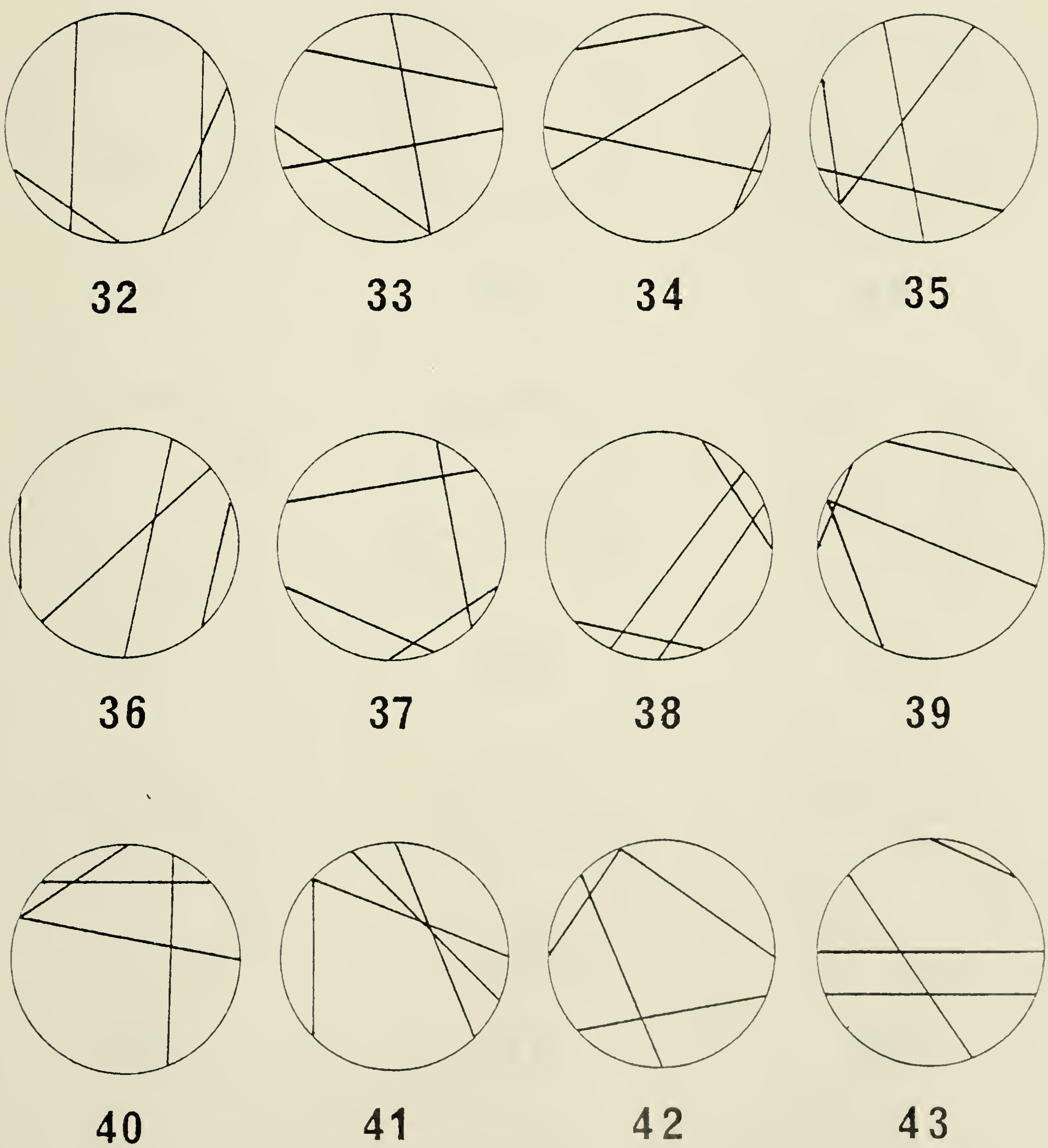


FIGURE 27

FIVE, SIX, AND EIGHT SIDED RANDOM PATTERNS

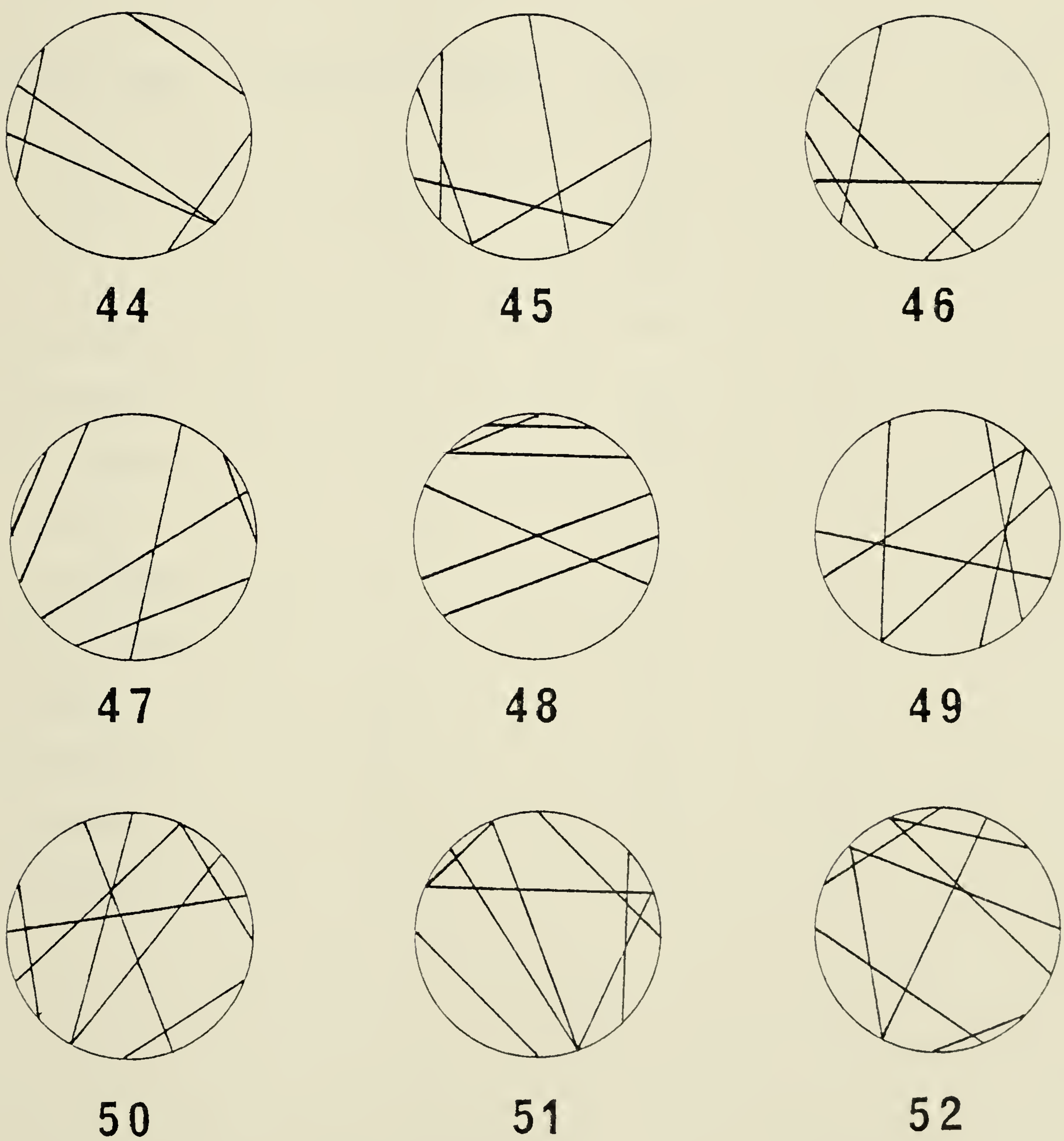


TABLE 3

NUMBER OF LABEL, YES, AND NO ANSWERS
TO MOVEMENT LISTS DRAWING GEOMETRIC FIGURES

Figure name	Sequence number	Label	Yes	No
"X"	1	44	2	4
"X"	2	48	1	1
"X"	3	45	1	4
Triangle	4	48	2	0
Triangle	5	45	3	2
Triangle	6	46	2	2
Square	7	46	3	1
Rectangle	8	44	4	2
Rectangle	9	46	3	1
Diamond	10	44	2	4
Pentagon	11	35	6	9
Hexagon	12	22	13	15
Octogon	13	40	6	4

TABLE 4

NUMBER OF LABEL, YES, AND NO ANSWERS
TO RANDOM LISTS OF TWO AND THREE MOVEMENTS

Number of movements	Sequence number	Label	Yes	No
2	14	7	5	38
2	15	34	1	15
2	16	27	4	19
2	17	6	3	41
2	18	14	3	33
2	19	15	3	32
2	20	23	3	24
2	21	12	9	29
2	22	28	1	21
3	23	16	8	26
3	24	17	8	25
3	25	20	6	24
3	26	19	3	28
3	27	19	11	20
3	28	16	9	25
3	29	19	11	20
3	30	23	8	19
3	31	11	2	37

TABLE 5

NUMBER OF LABEL, YES, AND NO ANSWERS
TO RANDOM LISTS OF 4, 5, 6, AND 8 MOVEMENTS

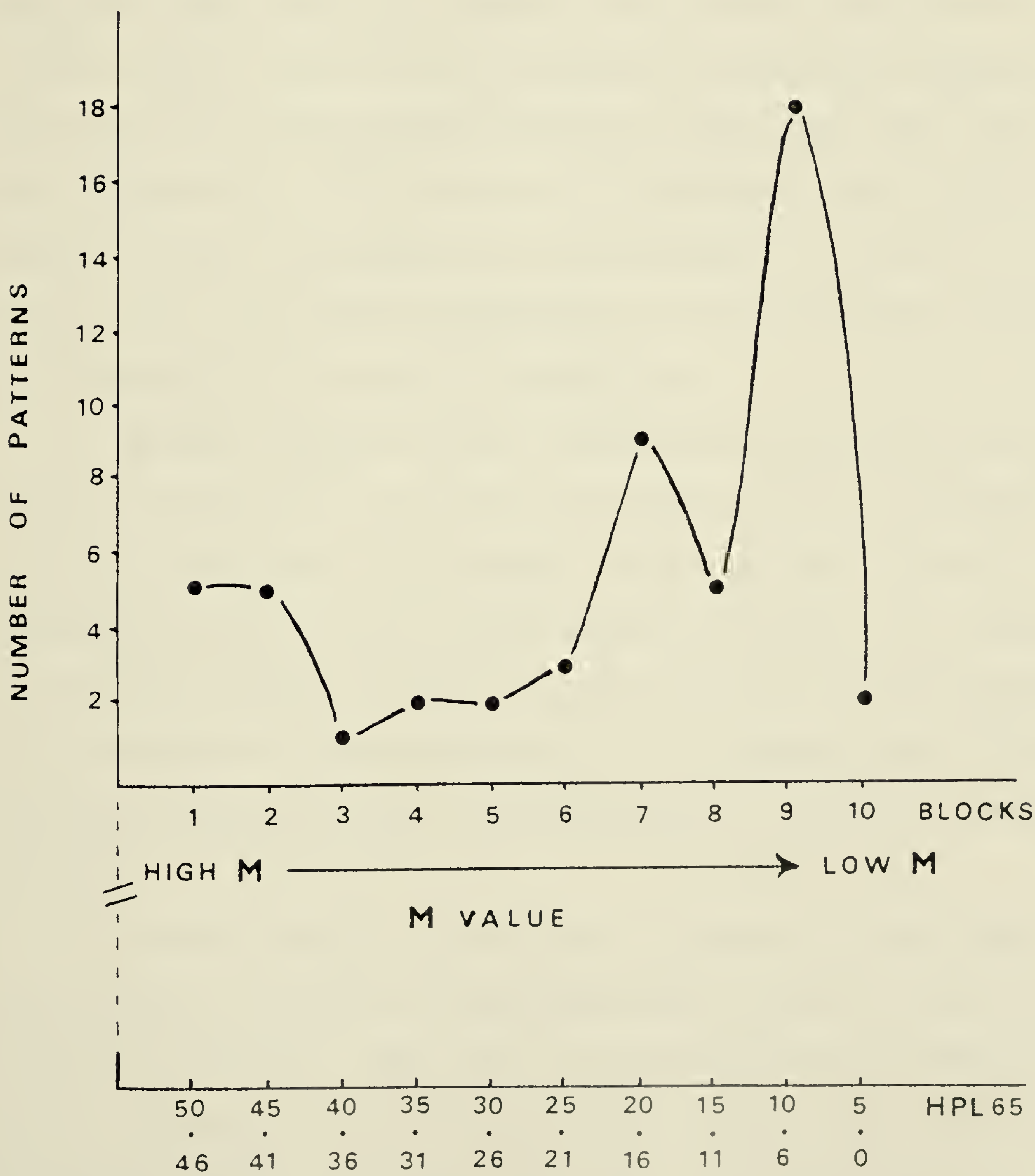
Number of movements	Sequence number	Label	Yes	No
4	32	10	6	34
4	33	18	7	25
4	34	9	11	30
4	35	6	9	35
4	36	10	10	30
4	37	9	9	32
4	38	16	12	22
4	39	8	12	30
4	40	10	4	36
4	41	8	5	37
4	42	9	13	28
4	43	4	2	44
5	44	7	9	34
5	45	9	6	35
5	46	8	8	34
6	47	7	5	38
6	48	9	9	32
6	49	5	9	36
8	50	9	6	35
8	51	9	7	34
8	52	11	3	36

FIGURE 28

DISTRIBUTION OF MEANINGFULNESS VALUE

FOR 52 MOVEMENT PATTERNS

(13 geometric figures vs 39 random patterns)



Discussion

The first important finding of this study, was that a large number of subjects were able to label the movement patterns presented in Experiments 3, 4, and 5 (Table 3). This finding supports the assumption of interconnectedness of image and label (Paivio, 1971; Paivio & Csapo, 1973), implying that nonverbal images evoked their associated verbal labels. And more importantly, since the complete assumption of interconnectedness of image and label have been supported in this series of investigations on motor memory, these two components are proposed to be part of the motor code, and useful components to the encoding, retention, and retrieval of movement information.

A second finding is the variability in level of meaningfulness (Figure 28), for the 52 movement patterns presented in this experiment. The range of this variability was extending from 4 to 48 (these numbers represent the smallest and largest number of label responses given by the subjects for different movement patterns). It suggests that different movement patterns differ substantially in level of meaningfulness.

A third finding, constitutes a support to the large variability in level of meaningfulness, found for the 52 movement patterns. The level of meaningfulness (number of label responses) of the 13 geometric figures was found to be significantly different ($p < .001$) from the level of

meaningfulness of the 39 random patterns. The level of meaningfulness of the same 13 geometric figures was also found to be significantly different from the level of meaningfulness of the 13 lowest meaningful patterns ($p < .001$). This last finding allow the author to call high M, the 13 geometric figures presented in Experiments 3, 4, and 5, and low M, the 13 random patterns which had the lowest number of label responses.

Finally, inspired by Vanderplas & Garvin's (1959) work, the author provides by this experiment a scale of meaningfulness for 52 different movement patterns (Tables 3, 4, 5).

The main reason to have chosen M value instead of imagery (I) value was brought by the definition of meaningfulness as a relation (Noble, 1952) or an association (Vanderplas & Garvin, 1959) between items. It was the purpose of these studies to test the S's capabilities to make associations between movement items. It was assumed that the low M movement items were low in I value (Paivio, 1976).

The preceeding experiment was necessary to the realisation of Experiment 7, the purpose of the latter experiment being to test the assumption of independence (Paivio & Csapo, 1973) of image and label components of the motor code.

It seemed evident to the writer that the only possible procedure to investigate the assumption of independence of the image and label components of the motor code would be to isolate each component alternately. Paivio & Csapo (1969) investigated the assumption of independence of the two codes, by varying the speed of presentation of pictures and words. Consequently, when the rate was accelerated for picture presentation, Ss could not label the pictures and a dramatic change in performance was observed. They explained that the equal recall performance for words and pictures demonstrated an equivalence between the encoding of the two types of stimuli and was a support to the independence assumption.

It is impossible to use a speed of presentation paradigm in the memory of movements, since it takes two to three seconds

for one movement presentation, which is considered to be a slow rate in this type of paradigm (Paivio & Csapo, 1969). Therefore, the isolation of the image and label components was realized by varying the degree of meaningfulness of movement items. In other words, the investigator was expecting that a presentation of low M movement items would not produce any transformation of one component (image) into the other (label), and hence would be a reliable method of testing the independence of the two components.

The same instructional strategies (imagery and imagery-labelling) and the same experimental procedure as Experiment 3 were used in Experiment 7, the exception being that the movement patterns were low M and the labels attached with the patterns, low M words taken from Noble's (1952) experiment. However, since low M movement items were presented for recall, a lower percentage of recall was expected, compared to Experiment 3 whereas high M movement items were presented. The reason to expect those results was that usually the "manipulation of meaningfulness affects semantic coding" (Levy & Craik, 1975, p. 34). High M items are usually retained better than low M items, demonstrating the effect of levels of processing on free recall (Craik & Lockhart, 1972). Therefore, a whole depression of the SPC was expected (Experiment 7) for the low M items (Seamon & Murray, 1976), compared to the high M items (Experiments 3, 4, 5).

The movement lists of Experiment 7 had the same

characteristics as the ones presented in Experiments 3, 4, and 5, with the exception of the degree of meaningfulness; this means simply that each of the five lists were made by the same number of 2, 3, 4, 5, 6, and 8 sided figures as the ones presented in Experiments 3, 4, and 5. Finally, since there were no significant differences between the three orders of presentation used in Experiments 3 and 5, only one order was chosen for presentation. The control condition (no strategy) was presented first, to prevent the use of strategies by the subjects. The labelling condition was presented second and the imagery condition last, in order to respect the basic assumption of this study, that labels would not elicit mental representative images and that images would not elicit verbal labels.

The purposes of Experiment 7 were : 1) to test the independence assumption of the image and label components of the motor code, and 2) to investigate the level of processing effect of low M, compared to high M movement items on free recall (Seamon & Murray, 1976).

Experiment 7

Level of processing and effects of image and label on the free recall of low meaningful movement patterns

Method

Subjects

The subjects were eight volunteers, graduate students in Physical Education at the University of Alberta.

Apparatus and task

The apparatus and task were the same as Experiment 3.

Design

The first experimental design was a 3 x 2 x 5 factorial with repeated measures on all factors. The first factor consisted of three levels of instructions: a) a control (C) (no strategy), b) an imagery strategy (I), and c) a labelling strategy (L). The second factor had two levels of recall: a) an immediate, and b) a final recall. The third factor consisted of five replications under each experimental condition.

The second experimental design was a 4 x 2 x 3 with repeated measures on the last two factors. The first factor (Factor A) had four levels of meaningfulness: a) high M movement patterns (High 1, High 2, High 3) (the three groups of Experiments 3 and 5 were considered), and b) low M movement patterns (Low 1) (Experiment 7). The second factor (Factor B) consisted of two recall conditions: a) an immediate and b) a final recall. The third factor (Factor C) had three levels of instructions: a) a control (no strategy), b) an imagery strategy, and c) a labelling strategy.

Procedure

The partitioning of the sessions and the procedure followed was similar to that used in Experiment 3.

Data analysis

The data were recorded (dependent variable) in terms of probability of correct recall under each experimental condition and each serial position in the list (Figures 29, 30, 31, 32). The amount of admissible transformation was restricted to 22.5° either side of the expected response (Figure 5).

Two analyses of variance were calculated to determine if there were significant differences between the levels of meaningfulness (High 1, High 2, High 3, versus Low 1), the levels of recall (immediate, final) and the levels of instructions (C, I, L). In cases of significance (*F* value) Scheffé was used for post hoc comparisons.

For purposes of interpretation, the criterion for rejecting the null hypothesis following statistical analysis, was $p < .01$.

Results

Two analyses of variance were performed on the data. The first one was a three way analysis of variance using the same Ss across conditions, and the second one a three way analysis of variance with different Ss across the different levels of meaningfulness.

The results of the first analysis provided significant differences between the three levels of instructions (C,I,L) $F(2,14) = 18.52$, $p < .001$, and the two levels of recall (immediate and final), $F(1,7) = 32.73$, $p < .001$ (Figure 29, Appendix B). There were no significant interaction effects, and no significant differences between the five replications of the same Ss under each experimental condition, $F(4,28) = 0.06$, $p > .05$ (Appendix B).

The Scheffé test on means was used for post hoc comparisons and revealed that the significant differences for the levels of instructions were located between (C) and (I), and (I) and (L) at $p < .001$, whereas (C) and (L) did not differ significantly from each other ($p > .05$).

The results of the second analysis provided significant differences between the four levels of meaningfulness (High 1, High 2, High 3, Low 1), $F(3,28) = 6.07$, $p < .01$, the two levels of recall (immediate and final), $F(1,28) = 129.39$, $p < .001$, and the three levels of instructions (C,I,L), $F(2,56) = 77.91$, $p < .001$ (Figure 30, Appendix B). The same analysis also revealed a significant levels of meaningfulness x levels of

FIGURE 29

PERCENT CORRECT RECALL

OF LOW MEANINGFUL MOVEMENTS

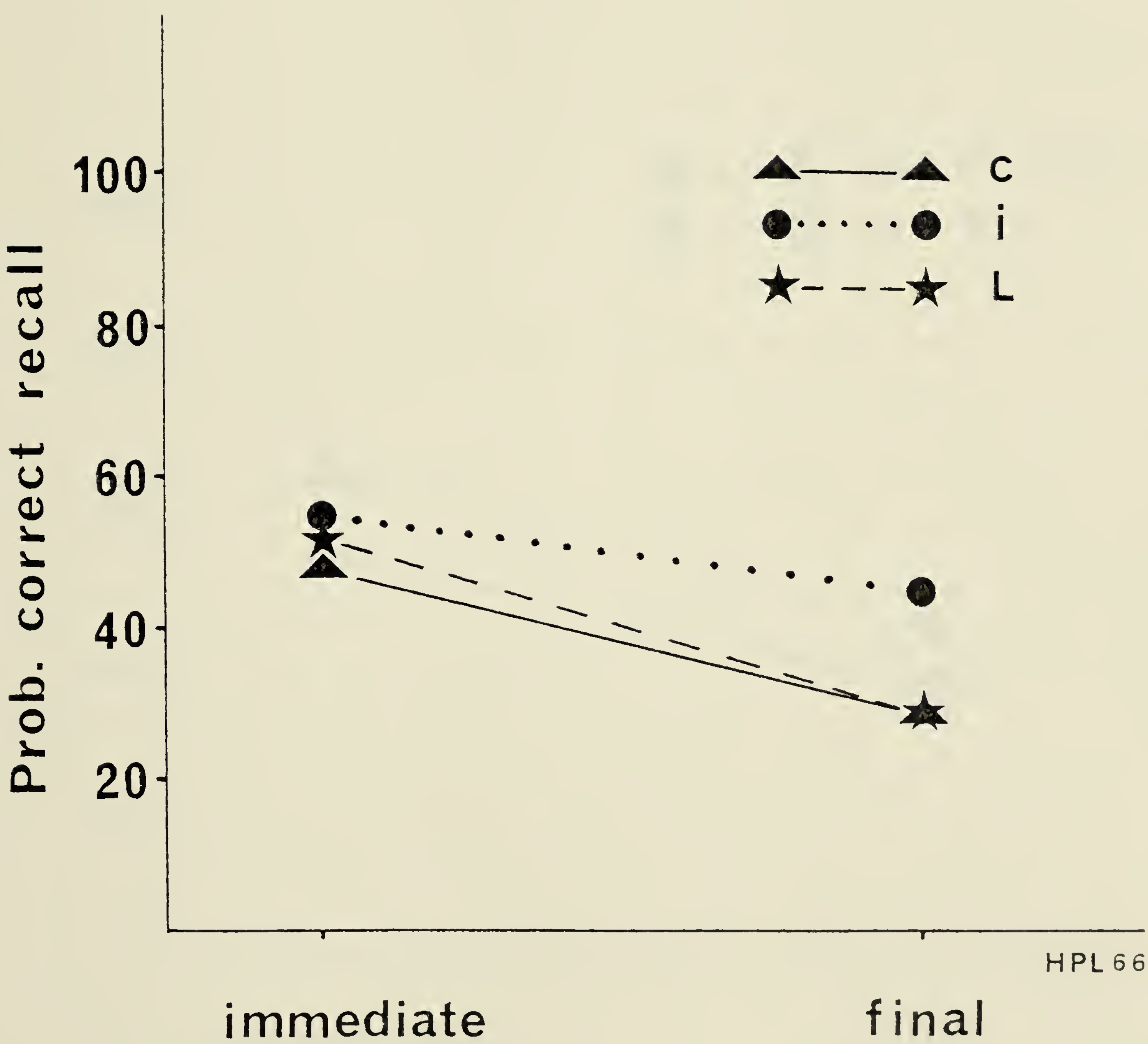
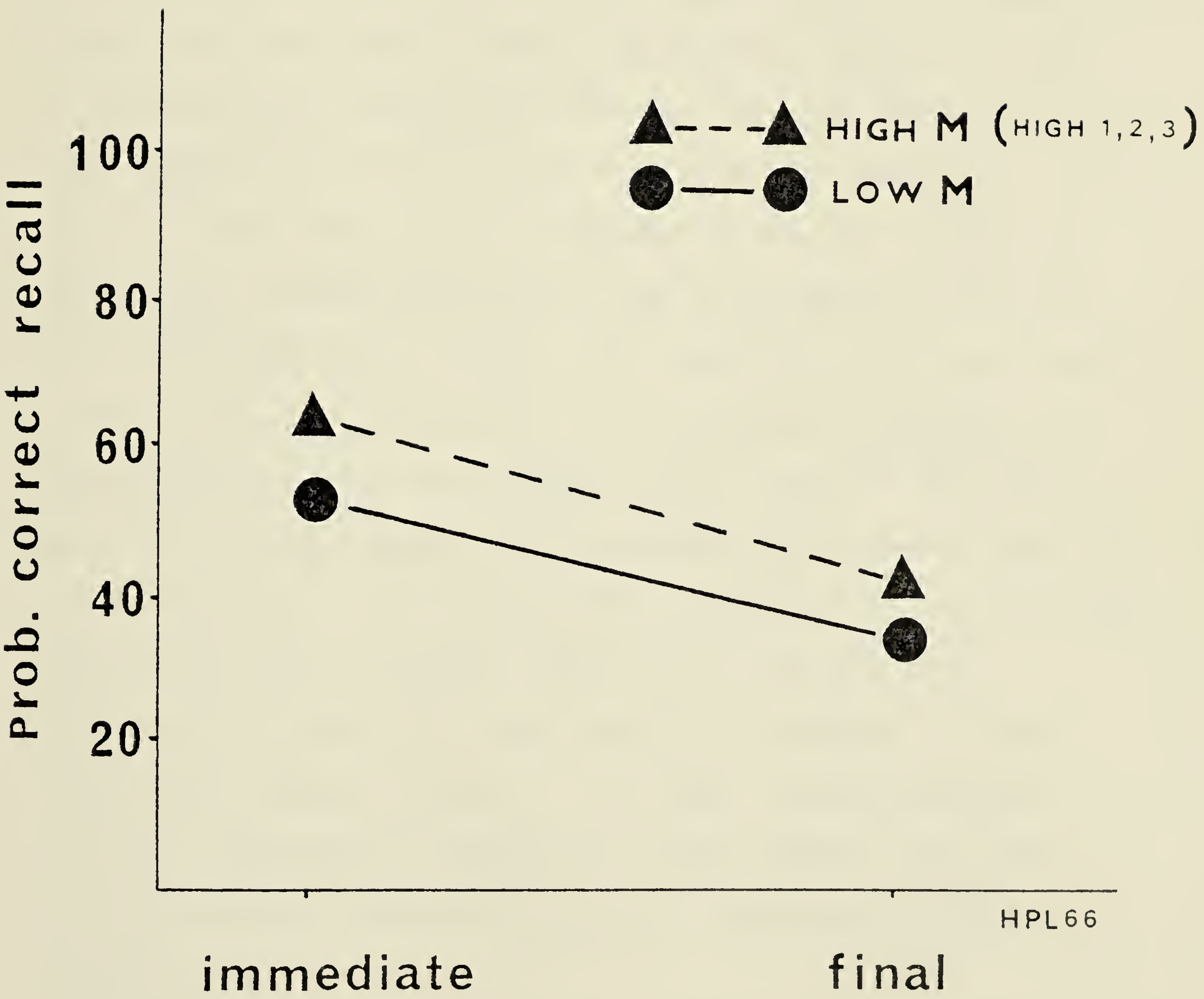


FIGURE 30

PERCENT CORRECT RECALL

OF LOW AND HIGH MEANINGFUL MOVEMENTS



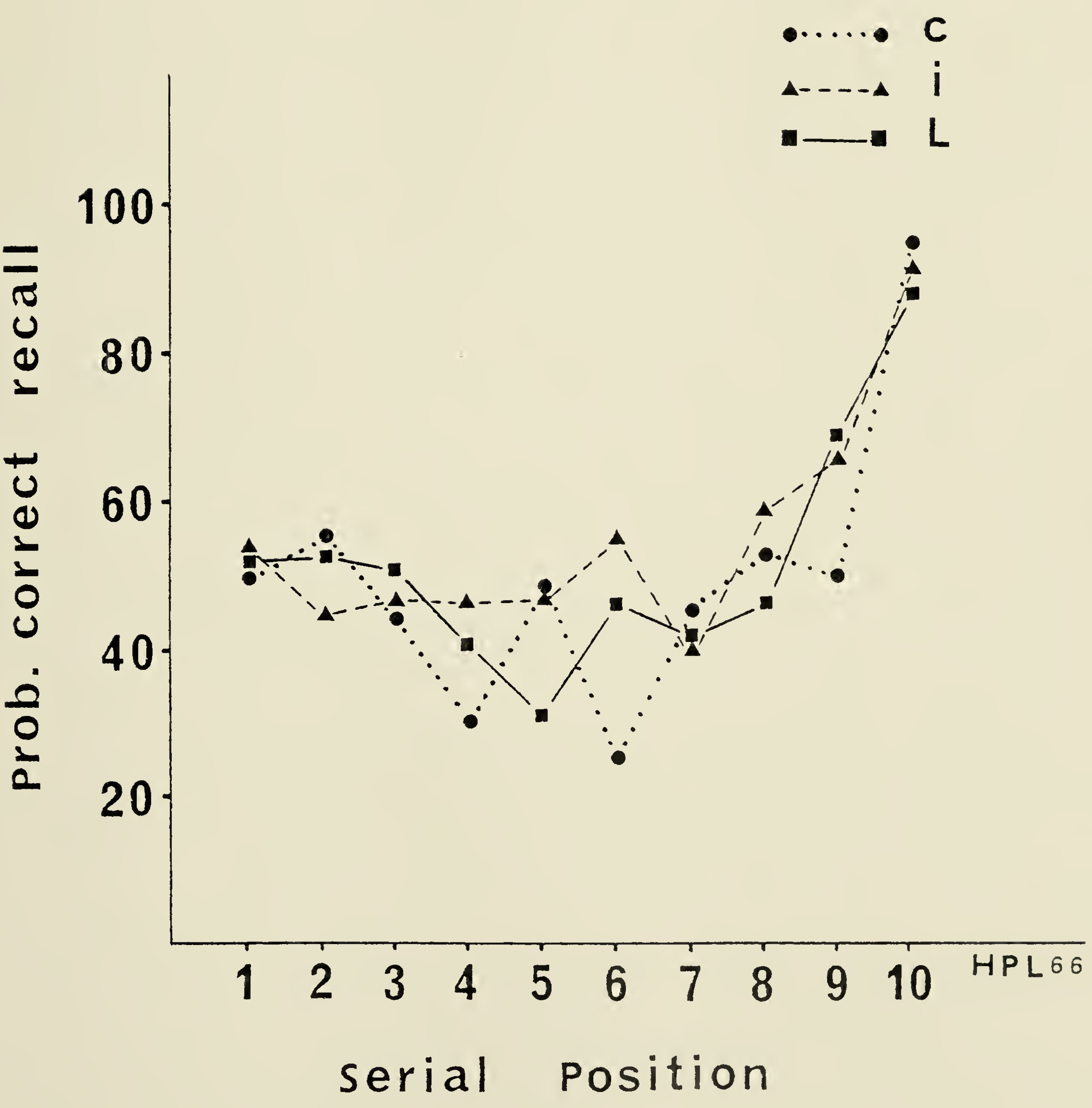
instructions interaction effect, $F(6,56)= 15.67$, $p < .001$ and a significant levels of meaningfulness x recall x levels of instructions interaction effect, $F(6,56)= 3.18$, $p < .01$ (Appendix B).

The Scheffé test on means was used for post hoc comparisons and indicated that high M movement items (High 1, High 2, High 3 were collapsed) differed significantly from low M movement items, at $p < .025$ (Appendix B). It was also found from the levels of meaningfulness x recall x levels of instructions interaction effect, that the final recalls were significantly lower ($p < .01$) than the immediate recall for: a) both high and low M movements and for b) all the control and labelling groups. The only exception was the lack of significance between the immediate and final recall of the I group who received low M movements (Appendix B). Another important point brought by the results from the same interaction effect was the difference between high and low M movements. This last difference existed only for the labelling groups, whereas there were no significant differences between the high and low M movements of the control and imagery groups. This last finding suggests that the significant differences found between high and low M movements were due only to the labelling groups (Appendix B).

The probabilities of correct recall for the low M movement items are presented under each recall condition (Figure 29) and each serial position (Figure 31).

FIGURE 31

IMMEDIATE RECALL
UNDER EACH SERIAL POSITION
FOR LOW MEANINGFUL MOVEMENTS



Finally, the probabilities of correct recall for high and low M movement items are presented under each recall condition (Figure 30) and each serial position (Figure 32).

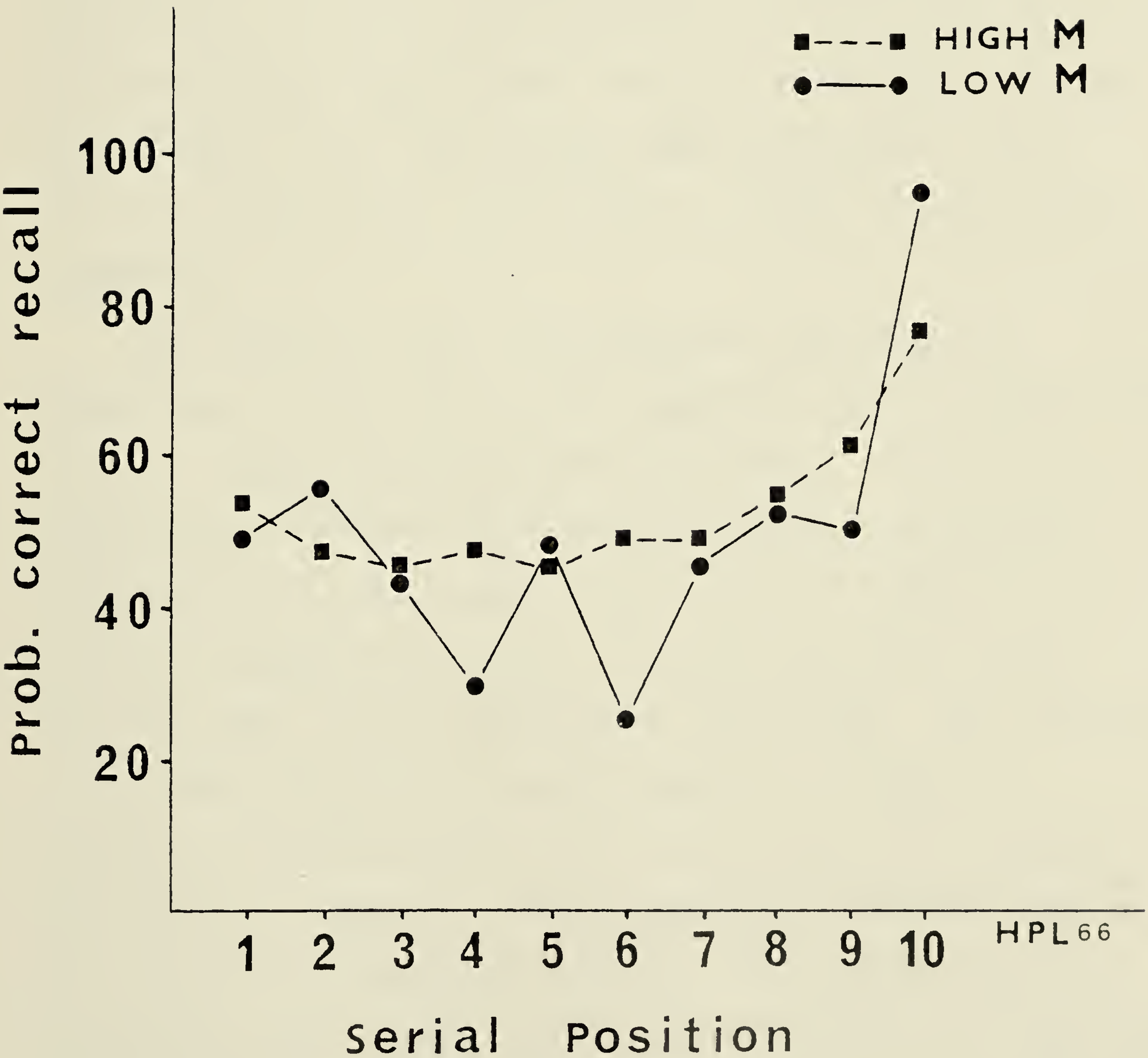
FIGURE 32

IMMEDIATE RECALL

UNDER EACH SERIAL POSITION

FOR LOW AND HIGH MEANINGFUL MOVEMENTS

(Control groups)



Discussion

The first purpose of this experiment was to test the independence assumption of the image and label components of the motor code. In order to test this assumption, the basic compulsory step was that images would not elicit labels and labels images. The methodology used by Paivio & Csapo (1969) to test this assumption was a speed of presentation paradigm. However, this paradigm being impossible to realize in experiments on motor memory, a new methodology was proposed using low M movement patterns (Experiment 6) and low M words taken from Noble (1952). This new methodology constituted an attempt to test this assumption.

The results of the first analysis indicated no significant differences at the immediate recall between the control, imagery, and labelling conditions. The lack of significance between the three instructional strategies supported by the S's comments following the experimental sessions, suggested that the strategies used by the Ss were the same in all experimental conditions. The similarities of the SPC's support the same suggestion (Figure 31). Therefore, the isolation of the image and label components may not have happened. The Ss themselves reported that in the control (no strategy) condition they were using both kinesthesis and imagery (mental representation) to reproduce the movements. In the labelling condition they found the label to generally be irrelevant to the recall of movements

and they prefered using kinesthesis and imagery. Finally, in the imagery condition the Ss tried to put more the emphasis on a mental representation of the image of the movements in memory.

These anecdotal reports suggest an important point of discussion. A fundamental difference exists between Paivio's experiments and this series of investigations. Paivio (1971) mentioned the contribution of two codes (image and label) for the recall of verbal information. These experiments have to consider the contribution of a third component for the recall of movement information, that is the kinesthetic component. Despite the fact that a strategy asking the Ss to concentrate on the kinesthetic sensation of the movement do not produce any significant improvement in recall accuracy (Gomez-Toussaint & Chevalier-Girard, 1975), the Ss of this experiment considered the information coming from the joints and the muscles as being a major contribution to the reproduction of movements. When appropriate labels were associated with series of movements they were considered as relevant to the task and labelling became a useful component for the recall of movements (Experiments 3, 4, 5). However, since in this experiment (Experiment 7) the Ss considered the labels as irrelevant to the task, the labelling component did not contribute to the recall of movement information. It is suggested that kinesthesis and imagery are the two basic components that contribute to the encoding, retention, and

retrieval of movement information. Further, labelling can be a relevant component if it is appropriate to the task demands. The important contribution of imagery (supported by the results of Experiment 7) indicates that no significant loss of information occurs during a 24 hours interval prior to recall, for the group that was instructed to emphasize imagery (Figure 29, Appendix B). As a result of failing to isolate imagery from labelling, this experiment failed to test the assumption of independence of image and label. It was found that imagery was used in all conditions (high or low meaningful) whereas labelling appeared to be used only when the movements were highly meaningful to the Ss.

This last point leads to the discussion between high and low M movement items. It was found that for the control and imagery groups, the recall of high M movements was not superior to the recall of low M movements (Figure 30). The only difference in recall of high versus low M movements existed when labelling was proposed as a strategy (Appendix B, ABC interaction). The substantial difference ($p < .01$) found between the labelling high M groups and the labelling low M group suggests the contribution of the labelling component as being a help only for the encoding, retention, and retrieval of high M movements. This suggests that the labelling component was not part of the motor code when low M movements had to be retrieved. These results support Shea's (1977) findings, that the use of relevant verbal labels aid in the recall accuracy of motor responses.

Finally, the finding of Seamon & Murray's (1976) experiment demonstrating a whole depression of the SPC for the low M items compared to the high M items, is not supported in this study. There was no significant depression of the SPC for low M movements compared to high M movements (Figure 32).

GENERAL DISCUSSION

The encoding characteristics of single items have been the object of several investigations in the literature on motor memory. These investigations were developed from two major historical viewpoints. The decay theory supposed that when we learn something, a memory trace is formed. This trace will gradually fade away if the imprint is not occasionally reactivated. The way we remember is to actively rehearse and keep these traces active. Thorndike (1913) felt that memory and forgetting were explained by his law of connection between stimulus and response. This hypothesis of a slowly desintegrating connection was one of the first statements of the position that forgetting was simply a matter of trace (or connection) decaying with the passage of time. This viewpoint held (Broadbent, 1958; Brown, 1958) a good deal of popular, subjective appeal. However, there was nothing to explain what it is that causes this desintegration, what determines its rate, or why in fact it even occurs (Cermak, 1972).

In a scathing attack on decay, as an explanation for forgetting, McGeoch (1932) advanced that time does not cause "deterioration" of memory, but what is learned during that time blocks retrieval of what you now want to remember. McGeoch felt that once something was learned, it remained permanently in memory and never decayed. However, as we continue to learn and form permanent memories, one

fact competes with the recall of another similar fact. This blocking or competition is today called "interference".

Each of these theories of memory was originally devised as an attempt to explain all phenomena occuring in memory. They both accounted the deterioration of memory, to the changes of the criterion trace (Stelmach, 1974).

The desintegration of the trace observed in memory for movements, received some support from the decay theory (Adams & Dijkstra, 1966). However, the incapability of the theory to explain the causes of the desintegration, contributed to the popularity of the interference theory. This last theory has been the focus of considerable interest in the literature on motor short-term memory (Montague & Hillix, 1968; Ascoli & Schmidt, 1969; Stelmach, 1970; Stelmach & Wilson, 1970; Pepper & Herman, 1970; Stelmach & Walsh, 1973). The purpose of the interference paradigm was to examine the information-processing demands in recalling single movements (Stelmach & Wilson, 1970). Short movements were considered to be encoded differently than the long ones, and the movement attributes (location, distance) were found to require different processing capacities (Posner, 1967; Keele & Ells, 1972; Laabs, 1973). It was suggested that spatial-location information received from the kinesthetic modality requires more 'central' processing capacity than distance information.

Despite the fact that a desintegration of the trace was evident in memory for single movements, nobody until that time had tried to optimize the encoding, retention and recall

of movement information, by making the movement information meaningful to the subject. Since the meaningfulness of the material seemed to be logically related to the strategies of encoding, retention and recall, the strategies used by the Ss during an experiment had to be controlled. Stelmach (1974) was saying: "When a subject is presented with a certain movement and is told that he will be required to reproduce this movement latter, what strategies does he employ" (p. 25). The introspective reports from subjects indicated that various coding strategies were used by the Ss. These strategies could take a variety of forms such as: counting, verbal labels, spatial representations, etc. Stelmach (1974), suggested that a fuller knowledge of the part played by subject-used strategies is important to our understanding of the mechanisms underlying human memory. Nacson, Jaeger & Gentile (1972) had already recognized the need for the S to organize and structure the information presented; that is to develop a strategy or plan to assimilate the new material. Kinesthetic information, Posner (1967) suggested, was transformed in an extremely brief visual form. Posner (1967) was referring to the physical representation of the movements in memory.

The encoding characteristics of multiple items received very little interest in the literature on motor memory (Cratty, 1963; Zaichkowski, 1974; Wrisberg, 1975; Magill, 1976; Magill & Dowell, 1977). The interest for the author of knowing the nature of motor memory for multiple items

constituted a starting point to this series of investigations. Experiments 1 and 2 were designed to determine if a SPC existed in motor memory, by using a free recall paradigm. The results supported Magill & Dowell's (1977) findings that a SPC exists for movement information when the lists exceed memory span (Posner, 1967). Although Magill & Dowell (1977) used a serial recall paradigm, they found a serial position effect for the lists of nine movements. This finding supports the results of Experiment 2 of this series that SPC's exist for the lists of 10 and 12 movements. No SPC were found when the amount of information was within memory span.

The major questions of this series of investigations concerned the encoding (what is stored), retention (how it changes over time) and retrieval (how it is used at the time of test) characteristics of multiple movement items. Now that the organization in memory for series of movements was known (SPC arrangement) the question was to find out what was stored in memory when movement informations were presented for recall. Posner (1967) referred to an imagery process as being part of the encoding of movement information. Brown (1976) and Shea (1977) recognized the facilitation in recall performance when relevant labels were provided with movement information. It was hypothesized that an imagery process would be used for the retention of movement information, and this imagery process would be interconnected and independent of a labelling process (Paivio, 1971;

Paivio & Csapo, 1973).

The results of Experiments 3, 4, and 5, demonstrated a significant better recall performance when an imagery strategy was used, compared to no strategy. When imagery and labelling were both used as strategies for recall, the performance was significantly improved compared to an imagery strategy only. The results of these experiments also supported Paivio's (1971) assumption of interconnectedness of image and label, implying that labels evoked their associated mental representations. The same results also supported Paivio's (1971) assumption of independence of image and label, in the sense that the two codes have additive effects on recall. When imagery and labelling were used as strategies for an immediate or a final recall (24 hours later), the whole SPC was disturbed demonstrating no primacy or recency effect. Imagery and labelling were not found to benefit more the primary or secondary part of the SPC, but benefited the recall of all the items in the lists (Experiments 3, 4, 5). In some cases the use of imagery reduced the decay after 24 hours (Experiments 4, 7). It was concluded that imagery and labelling were part of the motor code.

The movement information presented to the Ss in Experiments 3, 4, and 5, were considered high M in the sense that they could be easily related to the S's past experiences. However, there was no experimental support to this assumption. The relevant motor memory literature was totally non-existant

on the concept of meaningfulness in movement items. Different movement patterns were shown to vary in levels of meaningfulness (Experiment 6). The movement patterns presented in Experiments 3, 4, and 5, were found to be high M, since the Ss could attach labels to them. Several movement patterns were found to be low M. These findings support Vanderplas & Garvin's (1959) experiment to the fact that random patterns vary in levels of meaningfulness.

High M items are usually recalled better than low M items (Peterson, Peterson & Miller, 1961; McNulty, 1965; Craik & Lockhart, 1972). For Craik & Lockhart (1972) this distinction reflects the level of processing on free recall. The applicability of these evidences were investigated in Experiment 7 of this series, for low and high M movement items. The high M movement items were not found to be recalled significantly better when no strategy or an imagery strategy were used. The only difference between the labelling high M and low M conditions was explained in terms of relevance or irrelevance of the verbal labels. In Experiment 7 the Ss found the verbal labels totally irrelevant to the recall of movements. It was suggested that labelling contributes to the encoding of movement information only when the labels are relevant to the task demands. The lack of significant differences between high and low M movement items for the control and imagery groups, and the significant differences found between the high and low M labelling groups suggest that the only information that renders a movement item

meaningful for the S, is the label. Labelling can therefore be a very important component of the motor code and produce, associated with movement information, a substantial improvement in motor memory.

The results of this series of investigations support Craik & Lockhart's (1972) point of view, that the largest activation of interconnected components produces the deepest level of encoding. In these experiments, when the kinesthetic component was mainly activated (control conditions) the lowest recall was observed, implying the lowest level of encoding. When the kinesthetic and imagery components were activated (imagery conditions) the recall was significantly improved, implying a deeper level of encoding. And, when the kinesthetic, imagery and labelling components were available, the highest recall or the deepest level of encoding was observed.

Does the serial position results of these experiments support a single or dual memory process. Petrusic & Jamieson (1978) presented lists of unrelated words for free recall. The interpolation of a very demanding shadowing task (repeating aloud two-digit numbers presented at a very rapid, constant rate - 1.5/sec.) produced substantial amounts of forgetting at all serial positions. They interpreted their results as a support to the single process model, and questioned the dual model implying that early and late items in a list are held in different memory stores (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Several authors in the verbal literature, who supported a dual view (Smith,

Barrasi & Gross, 1971; Madigan, McCabe & Itatani, 1972) found imagery to benefit recall from secondary memory. However, the results of using an imagery strategy for the recall of movement information did not show to benefit more primary or secondary memory, but benefited the recall of all positions in the lists. Therefore, the results of the experiments of this series would support a single process view for the encoding of movement information.

In summary, the encoding characteristics of multiple items were found to present a serial position type of arrangement. Imagery and labelling were proposed to be legitimate components of the motor code, implying that these processes would be used for the encoding, retention, and retrieval of movement information. Finally, the results of these experiments supported a single process model in the memory for movement information.

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APPENDIX A

INSTRUCTIONS

Experiment 1

You will be seated and blindfolded in order to execute the task. You will wear the headphones throughout all the experiment. The joystick is located at your right or left depending on your preferred hand.

Your hand is on the handle throughout all the experiment and the handle can move in all directions in the circle. First, you will hear a single tone through the headphones. This signal tone indicates that a triangle (or three movements) will be described by the experimenter who will move the handle in three different directions, while your hand is always on the handle. Each time you hear a single tone, a triangle is described for you by the E, with the handle. When you hear two successive tones, you have to recall the sequence of triangles given before, by moving the lever by yourself. It doesn't matter if it's not in the order given by the E. You can recall the sequence of triangles in any order you wish.

Before the experiment starts, I am going to describe for you with the lever, the eight triangles which constitute the experiment (At this moment the subject is blindfolded but does not wear the headphones).

You have one practice trial before the experiment (The subject wears the headphones for the practice, which one is constituted of three movement triagrams).

Experiment 2

You will be seated and blindfolded in order to execute the task. Your hand is on the handle at your right throughout all the experiment, and the handle can move in all directions in the circle.

The E moves the handle for you while your hand is always on the handle. When you hear a continuous tone, a single movement is given by the E from the beginning to the end of the movement (example). After the first movement is given, the E moves the handle to the new starting point of the following movement. When the E moves the handle to a new starting point, there is no tone. Then you receive the second movement with a continuous tone, and then the E moves the handle to a new starting point (example). Each sequence of movements will follow the same procedure. The important thing is for you to remember only the movements given with the continuous tones.

After a sequence of movements is finished, you will hear two successive tones. By this signal you will know that you have to reproduce the movements given with a signal tone in the preceeding sequence, in any order you wish. It doesn't matter if it's not in the order given by the E. It doesn't matter for the order of the movements in the sequence and it doesn't matter for the order within each movement (example). What you have to do is reproduce first the movements you have first in mind or the ones you remember better.

You have to use the same procedure to reproduce the

movements. You have a buzzer in your left hand, and you have to push on the buzzer as long as you reproduce a movement of the sequence given before. When you move to the starting point of another movement you do not produce any tone. You produce a tone only for the movements that were given with a tone in the preceeding sequence.

I would like you to recall that the order in which you reproduce the movements is not important. The only movements that you have to remember are the ones given with a continuous tone. Finally, the movements are reproduced by yourself, in any order you wish, by producing a continuous tone from the beginning to the end of each movement of the sequence.

You have one practice trial before the experiment.

Experiment 3

Control

You will be seated and blindfolded in order to execute the task. Your hand is on the handle throughout all the experiment, and the handle can move in all directions in the circle.

The E moves the handle for you, while your hand is always on the handle. When you hear a continuous tone, a single movement is given by the E from the beginning to the end of the movement (example). After the first movement is given, the E moves the handle to the new starting point of the following movement. When the E moves the handle to a new starting point, there is no tone. Then you receive the second movement with a continuous tone, and then the E moves the handle to a new starting point (example). Each sequence of movements will follow the same procedure. The important thing is for you to remember only the movements given with a continuous tone.

After a sequence of movements is finished, you will hear two successive tones. By this signal you will know that you have to reproduce the movements given with a tone in the preceeding sequence in any order you wish. It does not matter if it is not in the order given by the E. It does not matter for the order of the movements in the sequence and it does not matter for the order within each movement (example). What you have to do is reproduce first the movements you remember better. In other words, you

reproduce first the movements you have first in mind.

You have to use the same procedure to reproduce the movements. You have a buzzer in your left/right hand, and you have to push on the buzzer as long as you reproduce a movement of the sequence given before. When you move to the starting point of another movement you do not produce any tone. You produce a tone only for the movements that were given with a tone in the preceeding sequence. I would like you to recall that the order in which you reproduce the movements is not important. The only movements that you have to remember are the ones given with a continuous tone. Finally, the movements are reproduced by yourself, in any order you wish, by producing a continuous tone, from the beginning to the end of each movement of the sequence.

You have a maximum of three practice trials to understand the procedure.

Imagery

For this part of the experiment I ask you to use a special strategy that might help you to remember the movements.

Each sequence of movements will be constituted by a certain number of geometric figures. I will say for example: Figure 1, and then I will give you a certain number of movements presented with a tone; those movements will constitute Figure 1. You will try to remember the movements by making the patterns or the geometric figures in your mind, with the movements that were presented with a signal tone. When I will say: Figure 2, you will try again to construct the geometric figures with the following movements accompanied with a signal tone.

I insist to say that each sequence will be constituted by a certain number of geometric figures. You will try to remember the movements by picturing the geometric figures in your mind. When you will hear two successive tones, you know that you have to reproduce the movements given with a tone in the preceeding sequence in any order you wish.

You have a maximum of three practice trials to understand the procedure.

Imagery+labelling

For this part of the experiment I will tell you before each sequence of movements, the name of the figures that will constitute the sequence, by order of appearance. And I will repeat before each figure of the sequence the name of this figure. What you try to do is again to make the pattern or geometric figure in your mind with the movements presented with a tone by the E. For example, when I say Figure 1, you know that the following movements presented with a tone, constitute Figure 1.

The procedure used will be the following one: first, I will give you the names of the figures in order of appearance in the sequence (example: rectangle, triangle, square). After, I will give you the name of the first figure and the movements that constitute this figure. I will do the same for the second and the third figure, etc. When you will hear two successive tones, you know that you have to reproduce the movements accompanied with a tone in the preceeding sequence, in any order you wish.

You have a maximum of three practice trials to understand the procedure.

Experiment 4

The instructions presented to the control and imagery+labelling groups of this experiment, are the same as the ones presented in Experiment 3 (see Instructions Experiment 3).

Experiment 5

Control

This condition follows the same format as those previously presented, with one exception - you are not to use a strategy to remember the movements.

I don't want you to try and picture a geometric figure in your mind. I want you instead, to focus on the start and end of each individual movement, so that you can give me each movement back as accurately as possible. Once again, order isn't important, just accuracy in how you give me the movements back.

Imagery

For this part of the experiment I ask you to use a special strategy that might help you to remember the movements.

Each sequence of movements (for example a sequence of 10 movements) will be constituted by a certain number of geometric figures. I will say for example: Figure 1, and then I will give you the movements that constitute Figure 1, accompanied with a tone. You will try to remember the movements by making the pattern or the geometric figure in your mind, with the movements given with tones. If for example, I give you a triangle, I don't want you to picture just a triangle but also its orientation as I am concerned with the accuracy of the start and end points of each line of the triangle. When I say: Figure 2, you try again to construct the geometric figure with the movements produced with tones.

I repeat that each sequence will be constituted by a certain number of geometric figures. You will try to remember the movements by picturing the geometric figures in your mind. When you will hear two successive tones, you know that you have to reproduce the movements given with tones in the preceeding sequence, in any order you wish.

You have as many practice trials as you want to understand the procedure.

Imagery+labelling

For this part of the experiment, I will tell you before each sequence of movements, the name of the figures that will constitute the sequence, by order of appearance in the sequence. And, I will repeat before each figure of the sequence the name of this figure.

What you try to do is again to make the pattern or the geometric figure in your mind with the movements accompanied with tones (example: when I say triangle you know that the three following movements given with tones will constitute a triangle. I am concerned not only that you remember the figures but also with the accuracy of start and end points of each individual line of the figure - so picture the figures orientation as I give it to you.

The procedure used will be the following one: first, I will give to you the names of the figures in order of appearance in the sequence (example: rectangle, triangle, square). After, I will give to you the name of the first figure and the movements that constitute this figure. I will do the same for the second and the third figure, etc. When you will hear two successive tones, you know that you have to reproduce the movements given with tones in the preceeding sequence, in any order you wish.

You have as many practice trials as you want to understand the procedure.

Experiment 6

You will be seated and blindfolded throughout all the experiment. You grasp the handle at your left/right and the E moves the lever for you while your hand is always on the handle. When you hear a continuous tone, a single movement is described by the E from the beginning to the end of the movement (example). After the first movement is given, the E moves the handle to the new starting point of the following movement. When the E moves the handle to a new starting point, there is no tone. Then you receive the second movement with a continuous tone, and then the E moves the handle to a new starting point, etc. Each sequence of movements will follow the same procedure. The important thing is for you to consider only the movements given with the continuous tones. When the sequence will be finished you will hear two successive tones (example). These two tones mean that it is the end of the sequence.

Your task is to try to picture in mind the movements given with tones. In other words, you try to picture what shape describes the movements put all together. Some sequences of movements built a shape. Some of the shapes may remind you of some familiar geometric figure, object, or situation, while others may not remind you of anything. Therefore, you will have three choices. The first choice is to describe in a word or two what the shape reminds you. The second choice is to say 'yes' if the shape reminds you something that you cannot express verbally in a word or two. And, the third choice is to say 'no' if the shape does not

remind you of anything. It is important that you say something, either a word if the shape reminds you of something that you can describe, or yes, or no, for each shape that is drawn by the E with the joystick. Questions ?

Experiment 7

Control

The instructions presented to the control group of this experiment, are the same ones as read to the subjects (control condition) of Experiment 3 (see Instructions - Experiment 3).

Imagery

For this part of the experiment I ask you to use a special strategy that might help you to remember the movements. Each sequence of movements (for example a sequence of 10 movements) will be constituted by a certain number of patterns. For instance, I will say: Pattern number 1, and then I will give you the movements that constitute Pattern number 1, accompanied with a tone. Your task will be to remember the movements by picturing the particular pattern in mind. When I will say: Pattern number 2, you will try again to construct the pattern that makes the movements given with the tones.

I repeat that each sequence of movements includes a certain number of patterns and you have to picture these patterns in mind. Not only the patterns by themselves are important to remember, but also the orientation of these patterns as I am concerned with the accuracy of the start and end points of each line of the patterns.

When the sequence is finished you will hear two successive tones. This signal indicates that you have to reproduce the patterns given before, in any order you wish. You have as many practice trials as you wish to understand the procedure.

Labelling

For this part of the experiment, I will associate some two syllable words with some series of movements. The procedure used will be the following one: first, before the sequence starts, I will give to you the words that will be associated with the series of movements of the sequence, by order of appearance in the sequence (example: matrix, icon, ulna). Then, I will repeat again the first word followed by his series of movements; then, the second word followed by his series, and finally the third word, followed by his series. Your task is again to remember the series of movements given with tones, but this time with the help of associated words.

When you will hear two successive tones you know that you have to reproduce the series of movements of the sequence given before, in any order you wish. The movements within the series can be in any order, as well as the series of the sequences (example). Finally, the order within each movement can be reproduced as you wish. It is assumed in this experiment that the words associated with the series of movements, will help you to remember the series.

You have as many practice trials as you wish to understand the procedure.

APPENDIX B

DATA ANALYSIS

Experiment 1

ANALYSIS OF VARIANCE TABLE

(measure: triangles)

Source	SS	DF	MS	F	PROB.
Between people	0.09928	7	0.01418		
Within people	0.28312	24	0.01179		
Treatments	0.11468	3	0.03822	4.76	.01
Residual	0.16844	21	0.00802		
Total	0.38241	31			

Treatments = Sequence lengths (3, 4, 5, 7 triangles)

SCHEFFE

FOR SEQUENCE LENGTHS

(measure: triangles)

	3 triangles	4 triangles	5 triangles	7 triangles
$\overline{X}$	0.900	0.844	0.790	0.739
	(1)	(2)	(3)	(4)

$Fc(3,28) = 2.95$, $p < .05$

Significant comparisons: (1) - (4)

ANALYSIS OF VARIANCE TABLE

(measure: movements)

Source	SS	DF	MS	F	PROB.
Between people	0.06036	7	0.00862		
Within people	0.25173	24	0.01048		
Treatments	0.12702	3	0.04234	7.13	.001
Residual	0.12471	21	0.00593		
Total	0.31210	31			

Treatments = Sequence lengths (9, 12, 15, 21 movements)

SCHEFFE

FOR SEQUENCE LENGTHS

(measure: movements)

	9 movements	12 movements	15 movements	21 movements
$\overline{X}$	0.930	0.881	0.830	0.760
	(1)	(2)	(3)	(4)

$Fc(3,28) = 4.57$, $p < .01$

Significant comparisons: (1) - (4)

Experiment 2

ANALYSIS OF VARIANCE TABLE

Source	SS	DF	MS	F	PROB.
A	0.47277	2	0.23638	2.56	
AS	1.29244	14	0.09231		
B	6.76515	3	2.25505	12.03	.001*
BS	3.93665	21	0.18745		
AB	1.61841	6	0.26973	4.05	.01*
ABS	2.79371	42	0.06651		
C	3.12679	2	1.56339	23.87	.001*
CS	0.91684	14	0.06548		
AC	0.15952	4	0.03988	0.39	
ACS	2.84110	28	0.10146		
BC	0.41827	6	0.06971	1.01	
BCS	2.91289	42	0.06935		
ABC	1.14423	12	0.09535	1.93	
ABCS	4.15294	84	0.04943		

A= Movement characteristics (closed, crossed, open)
B= Sequence lengths (5, 7, 10, 12 movements)
C= Replications
S= Subjects

SCHEFFE

FOR SEQUENCE LENGTHS

(B main effect)

	5 movements	7 movements	10 movements	12 movements
$\overline{X}$	1.583	1.112	1.058	1.124
	(1)	(2)	(3)	(4)

$Fc(3,284) = 5.42$, $p < .001$

Significant comparisons: (1) - (2)
(1) - (3)
(1) - (4)

SCHEFFE

FOR REPLICATIONS

(C main effect)

	R_1	R_2	R_3
$\overline{X}$	1.05	1.237	1.299

$Fc(2,286) = 6.91$, $p < .001$

Significant comparisons: $R_1 - R_2$

$R_1 - R_3$

SCHEFFE

FOR MOVEMENT CHARACTERISTICS X SEQUENCE LENGTHS

(AB interaction effect)

Sequence length	Closed	Crossed	Open
5	1.583 (1)	1.35 (2)	1.358 (3)
7	1.112 (4)	1.302 (5)	1.29 (6)
10	1.058 (7)	1.033 (8)	1.129 (9)
12	1.124 (10)	0.902 (11)	1.099 (12)

$F_c(11, 276) = 2.32$, $p < .01$

Significant comparisons of interest: (1)-(4) (2)-(11)
(1)-(7) (5)-(11)
(1)-(10)

Experiment 3

ANALYSIS OF VARIANCE TABLE

Source	SS	DF	MS	F	PROB.
A	20.59298	2	10.29649	45.37	.001*
AS	3.17699	14	0.22692		
B	5.82815	1	5.82815	29.72	.001*
BS	1.37249	7	0.19607		
AB	0.24233	2	0.12116	1.73	
ABS	0.98099	14	0.07007		
C	1.38816	4	0.34704	2.99	
CS	3.24916	28	0.11604		
AC	3.77033	8	0.47129	4.37	
ACS	6.03633	56	0.10779		
BC	1.20683	4	0.30170	2.16	
BCS	3.90915	28	0.13961		
ABC	1.00766	8	0.12595	1.46	
ABCS	4.83233	56	0.08629		

A = Levels of instructions (Control, Imagery, Imagery+labelling)
B = Recalls (Immediate, Final)
C = Replications
S = Subjects

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES

(A main effect)

	Control	Imagery	Imagery+labelling
$\overline{X}$	0.80775	1.1705	1.525
	(1)	(2)	(3)

$Fc(2,237) = 6.91$, $p < .001$

Significant comparisons: (1)-(2)
(1)-(3)
(2)-(3)

Experiment 4

ANALYSIS OF VARIANCE TABLE

Source	SS	DF	MS	F	PROB.
A	9.80099	1	9.80099	44.03	.001*
AS	1.55799	7	0.22257		
B	0.08099	1	0.08099	0.81	
BS	0.70199	7	0.10028		
AB	0.24024	1	0.24024	3.05	
ABS	0.55074	7	0.07867		
C	0.57937	4	0.14484	1.32	
CS	3.07962	28	0.10998		
AC	1.28212	4	0.32053	3.38	
ACS	2.65887	28	0.09495		
BC	0.77587	4	0.19396	3.23	
BCS	1.68112	28	0.06004		
ABC	0.19662	4	0.04915	0.55	
ABCS	2.52237	28	0.09008		

A = Levels of instructions (Control, Imagery, Imagery+labelling)
B = Recalls (Immediate, Final)
C = Replications
S = Subjects

Experiment 5

ANALYSIS OF VARIANCE TABLE

(Second order of presentation: I+L, C, I)

Source	SS	DF	MS	F	PROB.
A	15.11407	2	7.55703	47.04	.001*
AS	2.24924	14	0.16066		
B	11.88148	1	11.88148	17.42	.005*
BS	4.77315	7	0.68187		
AB	0.78524	2	0.39262	2.85	
ABS	1.93008	14	0.13786		
C	0.17191	4	0.04297	0.39	
CS	3.01607	28	0.10771		
AC	0.52633	8	0.06579	0.51	
ACS	7.27366	56	0.12988		
BC	0.37391	4	0.09347	1.20	
BCS	2.17807	28	0.07778		
ABC	0.24433	8	0.03054	0.30	
ABCS	5.66366	56	0.10113		

A = Instructional strategies (Control, Imagery, Imagery+labelling)
B = Recalls (Immediate, Final)
C = Replications
S = Subjects

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES

(Second order of presentation)

	Imagery+labelling	Control	Imagery
$\bar{X}$	1.31875	0.7275	1.169
	(3)	(1)	(2)

$Fc(2,237) = 4.7$, $p < .001$

Significant comparisons: (1)-(2)
(1)-(3)

ANALYSIS OF VARIANCE TABLE

(Third order of presentation: I, I+L, C)

Source	SS	DF	MS	F	PROB.
A	3.47024	2	1.73512	8.08	.005*
AS	3.00310	14	0.21450		
B	16.38030	1	16.38035	123.47	.001*
BS	0.92862	7	0.13266		
AB	1.07724	2	0.53862	5.32	.025
ABS	1.41874	14	0.10133		
C	0.59733	4	0.14933	0.91	
CS	4.58132	28	0.16361		
AC	0.88391	8	0.11048	0.73	
ACS	8.52941	56	0.15231		
BC	0.23483	4	0.58708	0.49	
BCS	3.33440	28	0.11908		
ABC	0.90691	8	0.11336	1.11	
ABCS	5.72374	56	0.10221		

A = Instructional strategies (Control, Imagery, Imagery+labelling)
B = Recalls (Immediate, Final)
C = Replications
S = Subjects

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES

(Third order of presentation)

	Imagery	Imagery+labelling	Control
$\overline{X}$	0.8625	1.1215	0.870
	(2)	(3)	(1)

$Fc(2,237) = 4.7$, $p < .01$

Significant comparisons: (1)-(3)
(2)-(3)

ANALYSIS OF VARIANCE TABLE

(Experiments 3 and 5 collapsed)[1]

Source	SS	DF	MS	F	PROB.
Bet.Subj.	4.36885	23			
A	1.12705	2	0.56352	3.65	0.0435
Subj.W.Group	3.24179	21	0.15437		
Within Subj.	19.04037	120			
B	6.49043	2	3.24521	80.92	0.0000002*
AB	1.34507	4	0.33626	8.38	0.0000457*
BxSubj.W.G.	1.68438	42	0.04010		
C	6.54446	1	6.54446	97.16	0.000001*
AC	0.27301	2	0.13650	2.03	0.156768
CxSubj.W.G.	1.41453	21	0.06735		
BC	0.15214	2	0.07607	3.69	0.033503
ABC	0.26971	4	0.06742	3.27	0.020234
BCxSubj.W.G.	0.86676	42	0.02063		

A = Orders of presentation (Order 1, 2, 3)
B = Instructional strategies (Control, Imagery, Imagery+labelling)
C = Recalls (Immediate, Final)

[1] This analysis includes the three orders of presentation of the instructional strategies.

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES

(Experiments 3 and 5 collapsed)[1]

	Control	Imagery	Imagery+labelling
$\overline{X}$	0.802	1.067	1.322
	(1)	(2)	(3)

$Fc(2,141) = 6.9,\ p < .001$

Significant comparisons: (1)-(2)
(2)-(3)
(1)-(3)

[1] This test includes the three orders of presentation of the instructional strategies.

SCHEFFE

FOR THE AB INTERACTION EFFECT

(orders of presentation x instructional strategies)[1]

	Days 1, 2	Days 2, 3	Days 3, 4
Order 1	C (1) .807	I (2) 1.170	I+L (3) 1.525
Order 2	I+L (6) 1.319	C (4) .727	I (5) 1.169
Order 3	I (8) .862	I+L (9) 1.121	C (7) .870

$Fc(8,135) = 2.64$, $p < .01$

Significant comparisons of interest :

(1) - (3)
(4) - (5)
(4) - (6)
(1) - (6)
(6) - (8)
(2) - (4)
(3) - (7)
(3) - (9)

(1) - (2)
(2) - (3)
(4) - (9)
(3) - (5)

1 Experiments 3 and 5 collapsed

SCHEFFE

FOR ORDERS OF PRESENTATION X INSTRUCTIONAL STRATEGIES X RECALLS [1]

(ABC interaction effect)

	Immediate recall			Final recall		
	Day 1	Day 2	Day 3	Day 2	Day 3	Day 4
	C (1) .967	I (2) 1.362	I+L (3) 1.64	C (10) .647	I (11) .977	I+L (12) 1.41
	I+L (6) 1.477	C (4) 1.025	I (5) 1.38	I+L (15) 1.16	C (13) .430	I (14) .957
	I (8) 1.030	I+L (9) 1.417	C (7) 1.19	I (17) .695	I+L (18) .825	C (16) .550

$Fc(17, 126) = 2.12$, $p < .01$

Significant comparisons of interest :

(1)-(3)	(12)-(16)	(12)-(18)
(10)-(12)	(4)-(13)	(13)-(14)
(13)-(15)	(9)-(18)	(1)-(6)
(11)-(13)	(7)-(16)	(10)-(15)
		(15)-(17)

Experiment 6

_T_ TEST

FOR INDEPENDENT UNEQUAL SAMPLES

(13 geometric figures versus 39 random patterns)

MEANS		S.D.				
GROUP 1	GROUP 2	GROUP 1	GROUP 2	DF	T	PROB.
42.5385	13.2564	7.066	7.003	50	13.03	0.0000

GROUP 1 = 13 geometric figures

GROUP 2 = 39 random patterns

T TEST

FOR INDEPENDENT EQUAL SAMPLES

(13 geometric figures versus 13 low M random patterns)

MEANS		S.D.				
GROUP 1	GROUP 2	GROUP 1	GROUP 2	DF	T	PROB.
42.5385	8.8462	7.066	3.869	24	15.08	0.0000

GROUP 1 = 13 geometric figures

GROUP 2 = 13 low meaningful random patterns

Experiment 7

ANALYSIS OF VARIANCE TABLE

(factorial 2 x 3 x 5)

Source	SS	DF	MS	F	PROB.
A	2.39908	2	1.19954	18.52	.001 *
AS	0.90691	14	0.06477		
B	8.14015	1	8.14015	32.73	.001 *
BS	1.74116	7	0.24873		
AB	0.80358	2	0.40179	4.32	
ABS	1.30108	14	0.09293		
C	0.02433	4	0.00608	0.06	
CS	2.68966	28	0.09605		
AC	0.36091	8	0.04511	0.78	
ACS	3.24308	56	0.05791		
BC	0.13733	4	0.03433	0.72	
BCS	1.33132	28	0.04754		
ABC	0.28891	8	0.03611	0.61	
ABCS	3.33641	56	0.05957		

A= Instructional strategies (Control, Imagery, Labelling)
B= Recalls (Immediate, Final)
C= Replications
S= Subjects

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES

(A main effect)

	Control	Imagery	Labelling
$\bar{X}$	0.7765	1.0015	0.8055
	(1)	(2)	(3)

$Fc(2,237) = 4.7$, $p < .01$

Significant comparisons : (1)-(2)
(2)-(3)

SCHEFFE

FOR INSTRUCTIONAL STRATEGIES X RECALLS

(AB interaction effect)

	Control	Imagery	Labelling
Immediate recall	0.988 (1)	1.105 (2)	1.043 (3)
Final recall	0.565 (4)	0.898 (5)	0.568 (6)

$Fc(5,235) = 3.1$, $p < .01$

Significant comparisons of interest : (1)-(4)
(3)-(6)
(4)-(5)
(5)-(6)

ANALYSIS OF VARIANCE TABLE

(factorial 3 x 2 x 3)

Source	SS	DF	MS	F	PROB.
Bet.Subj.	6.61309	31			
A	2.60525	3	0.86842	6.07	0.0025 *
Subj.W.Group	4.00784	8	0.14314		
Within Subj.	22.09857	160			
B	8.14263	1	8.14263	129.39	0.0000 *
AB	0.30316	3	0.10105	1.61	0.2103
BxSubj. W G	1.76201	28	0.06292		
C	5.18600	2	2.59300	77.91	0.0000 *
AC	3.12994	6	0.52165	15.67	0.0000 *
CxSubj. W G	1.86383	56	0.03328		
BC	0.19726	2	0.09863	4.89	0.0110
ABC	0.38501	6	0.06416	3.18	0.0093 *
BCxSubj. W G	1.12896	56	0.02016		

A= Levels of meaningfulness (High 1, High 2, High 3, Low 1)

B= Recalls (Immediate, Final)

C= Instructional strategies (Control, Imagery, Labelling)

SCHEFFE

FOR HIGH VERSUS LOW MEANINGFUL MOVEMENTS

(A main effect)

	High meaningful (High 1, High 2, High 3, are collapsed)	Low meaningful
$\overline{X}$	1.063 *	0.861 *

$Fc(3,188) = 3.12,\ p < .025$

SCHEFFE

FOR LEVELS OF MEANINGFULNESS X RECALLS X INSTRUCTIONAL STRATEGIES

(ABC interaction effect)

	Immediate recall			Final recall		
	Control	Imagery	Labelling	Control	Imagery	Labelling
High meaningful (High 1, High 2, High 3, are collapsed)	1.061 (1)	1.257 (2)	1.511 (3)	0.542 (7)	0.876 (8)	1.132 (9)
Low meaningful	0.987 (4)	1.105 (5)	1.042 (6)	0.565 (10)	0.897 (11)	0.567 (12)

Significant comparisons of interest : (3)-(6) (9)-(12) (1)-(7) (2)-(8) (3)-(9) (4)-(10) (6)-(12)

APPENDIX C

PHOTOGRAPHIC PLATES

Plate 1. View of apparatus

Plate 2. View showing position of subject, experimenter, and apparatus

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